PROCEEDINGS

Sixth Meeting of Agricultural Scientists

Bonâme Hall, MSIRI
Réduit, Mauritius, 8 - 9 May 2003

Organised by

The Food and Agricultural Research Council (FARC)

in collaboration with

The Agricultural Research and Extension Unit (AREU)

The Agricultural Services, Ministry of Agriculture,
Food Technology and Natural Resources

The Albion Fisheries Research Center (AFRC)

The Faculties of Agriculture and Science,
University of Mauritius (UOM)

The Mauritius Sugar Industry Research Institute (MSIRI)

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The Agricultural Research and Extension Unit functions under the aegis of the Food and Agricultural Research Council as from July 1995. The main objective of AREU is to serve its clients through excellence in cost-effective high quality research and extension and to meet the policy requirements of government. AREU has responsibility for livestock and all crops excluding sugarcane.

Agricultural Services, Ministry of Agriculture, Food Technology and Natural Resources
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The Agricultural Services of the Ministry of Agriculture, Food Technology and Natural Resources started life as the Department of Agriculture in 1913 itself taking over from the Station Agronomique created in 1893. It is the regulatory body of the Ministry and provides a number of services to the agricultural community.

Albion Fisheries Research Centre (AFRC)
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The objectives of the Albion Fisheries Research Centre are to carry out research and development activities with a view to increasing knowledge on fishery resources within the fishing limits of Mauritius and to provide a basis for their sustainable development and management.

Food and Agricultural Research Council (FARC)
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The Food and Agricultural Research Council was created in 1985. Its main objective is to promote, harmonise and co-ordinate research activities in agriculture, fisheries, forestry and food production in line with government policy and to ensure that the farming community draws the maximum benefits from such research.

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The Mauritius Sugar Industry Research Institute is a statutory body created in 1953 with mandate to promote by means of research and investigation the technical progress of the sugar industry. It also carries out research on foodcrops that are grown in association with sugarcane.

University of Mauritius (UOM)
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The University of Mauritius was founded in 1965. While training remains one of its important mandates, it also focuses on research in diverse areas which include agriculture and allied subjects.

CIRAD
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FOREWORD 2003

The 6th Meeting of Agricultural Scientists held by the FARC has come in a year critical enough to be aptly described as a watershed. As a matter of fact, Mauritian Agriculture has reached a crossroad. It has now to gear up to adjust away from the more or less comfort zone it has been in for years, to a new and probably ruthless global environment characterized by cut-throat trade competitiveness. And technology, mainly in the form of ICT and the biotechnologies, are being proposed as one strategic armament to leverage in the face of these looming challenges.

We were therefore particularly gratified, during this meeting, to have been amongst the first to be exposed to a most comprehensive and balanced review on biotechnology, derived from a study sponsored by the ICSU and undertaken by Gabrielle Persley. Mrs Persley’s crystal-clear presentation, during her keynote address, deals with the application of modern genetics in food, agriculture and the environment, and the associated complexities that all this raises.

Such an overview had become particularly timely in the context of our national effort in working out our future biotechnology policy; more specifically in our attempt to define an appropriate legislative framework and put up the required R & D infrastructure, through the proposed Mauritius Agricultural Biotechnology Institute (MABI), to maximise our chances of harnessing the potential and opportunities offered by biotechnology, while also ably managing any risk that these technologies may pose.

This year’s meeting again spans a wide range of research undertakings that, in a sense, reflect the priorities of the research institutions and individual scientists involved. Many of these research ventures coincide with the proposals contained in the Non Sugar Sector Strategic Plan (03/07) of the Ministry of Agriculture, Food Technology and Natural Resources.

Nevertheless, there is a need for finetuning of research priorities to respond to the increasingly complex issues facing our agro-industry. Such a task has to be undertaken in as independent and objective a manner as possible. This objective, in addition to that of information diffusion, underpins the mission of the FARC, and is being addressed by a Priority-Setting Committee where most of the concerned parties are collaborating.

We therefore expect to see the outcome in the deliberations of our future scientific meetings.

Finally, as usual, I am delighted to introduce these Proceedings, a reflection of the impeccable task accomplished by the Organising and Editorial Teams of the FARC. I reiterate my appreciation for their continuing excellence. My thanks extend also to all the researchers, institutions and individuals, including stakeholders from the private sector and NGOs, and not least our foreign collaborators, for their active participation which is so vital for these meetings to succeed and be fruitful.

Jairaj Ramkissoon

Director General
WELCOMING ADDRESS 2003

Dr T Bahorun

Chairman, FARC

Honourable Minister of Agriculture, Food Technology and Natural Resources
Excellencies of the Diplomatic Corps
Members of the National Assembly,
Chairman, Moka-Flacq District Council
Dr Gabrielle Persley
Members of the Peerun Family
The Permanent Secretary, Ministry of Agriculture Food Technology and Natural Resources
The Director MSIRI
Distinguished Guests,
Fellow Scientists
Ladies and Gentlemen

It is my pleasant duty this morning to welcome you to our 6th Meeting of Agricultural Scientists. This meeting is being organised by the FARC in collaboration with the Mauritius Sugar Industry Research Institute and the participation of Agricultural Research and Extension Unit, the Agricultural Services of the Ministry of Agriculture, the University of Mauritius and the Albion Fisheries Research Centre.

AMAS is now an established forum providing opportunities for Agricultural research organisations to present their findings and for young scientists to meet and exchange views. This year 38 papers have been peer-reviewed for presentation on various agricultural subjects and this high number is self-evident of the determination to strengthen research capacity within Mauritius and the region vital for sustainable growth in agricultural scientific development. I would like to mention that 2 of the 38 accepted papers are from our friends from CIRAD Réunion.

C’est donc avec un grand plaisir que nous accueillons les chercheurs du CIRAD de la Réunion parmi nous

I have also the great pleasure to welcome Dr Gabrielle Persley, advisor to the World Bank on Biotechnology, who will be delivering the keynote address of this opening session. We would like to express our gratitude to her for having so kindly accepted our invitation.

I would like to take this opportunity to highlight the terms of reference of FARC and situate its importance with regards to the pragmatic reforms spelt out in the non-sugar sector plan. In my opinion the honourable Minister of Agriculture, Food Technology and Natural Resources, Pravind Jugnauth, in his opening address at the 5th AMAS meeting held in 2001 well summarized this important role. In his speech he declared: (I quote)

“The foremost thrust of FARC would be of co-ordination, and strategic and integrated planning of Agricultural Research and development, with the long term sustainability of the agriculture/food/environmental sector. FARC being responsible for co-ordination will have to also organise public sector research institutions so that they can conduct research cost effectively, with a minimum of wasteful duplications of facilities and programmes. There is need for unified strategic research and applications plans for major priority national issues, which need the enlisting and integration of all potential participants. FARC would therefore, have to help by establishing guidelines, to encourage and facilitate pursuit of the purposes of research. In other words, clarifying the policy, methodology, planning and managements aspects of research”

In line with the Minister’s views, FARC is currently preparing a document on the status of Agricultural Research in Mauritius and Rodrigues. This will be a detailed compilation of ongoing and completed research projects on a filière basis over the last 3 years. It will also comprise an audit of existing infrastructure supporting research. With the collaboration of the operators of the public and private sectors, FARC will be launching a series of consultations to set up priority research areas. This
information will indeed be useful to initiate the implementation of the non-sugar plan and the setting up of the national biotechnology institute

I would like to have a special word of thanks for the Organising Committee, which has spared no efforts to prepare a stimulating scientific programme of plenary lecture, oral presentations and poster sessions.

Minister, Ladies and Gentlemen,

On behalf of the organising committee, I thank you for your presence at this meeting, and I have great pleasure and honour to kindly request the Honourable Minister of Agriculture, Food Technology and Natural Resources to make his address and formally open this meeting.
MINISTER’S ADDRESS 2003

Hon. Pravind Kumar Jugnauth,

Minister of Agriculture, Food Technology and Natural Resources

Colleague Ministers & Members of the National Assembly
Excellencies of the Diplomatic Corps
Chairman, Moka/Flacq District Council
The Permanent Secretary, Ministry of Agriculture, Food Technology & Natural Resources
Chairman and Director General, Food and Agricultural Research Council
Director, MSIRI
Dr. Gabrielle Persley
Members of the PEERUN family
Distinguished Guests and Participants

It is my pleasure to launch today the 6th Meeting of Agricultural Scientists, organised now as a regular feature, by the Food and Agricultural Research Council (FARC). I would like to extend a special welcome to our distinguished participants from overseas, namely Dr Gabrielle Persley who visited Mauritius in 1992 and 1995 and shared her expertise on biotechnology issues, and Messrs. Grimaud and Rousse from CIRAD, Reunion who are helping to enliven the regional significance of this meeting.

I am indeed honoured to address you this morning and to briefly share with you some of my thoughts about agricultural concerns of today and the role and contribution expected of food and agricultural research.

Ladies and Gentlemen, in this new modern era, the challenges facing agriculture have evolved into a significantly different nature. Agriculture is no longer the sole business of the day. And it is operating in a global, high-tech and consumer-driven environment.

Technology is constantly influencing world markets. With the transformation of the economy and society, our scientists and researchers are called upon to address an extended array of new issues. In addition to the traditional concerns about food costs, food security, productivity and trade competitiveness, many other societal issues related to modern farming have now come to the fore. These concern food and nutrition, safety and quality; consumer health, environmental protection; convenience and other quality-of-life issues; and even social and ethical dimensions such as workers’ rights and safety, and animal welfare.

Hence the challenge of having to expand the research agenda, without reducing existing priorities and against a backdrop of generally shrinking agricultural research budgets.

At the same time, research undertakings must be able to attract the trust of the public and the respect of the whole scientific community.

There is a pressing need therefore to develop consultation processes with stakeholders and the public to foster debate. A Science Information System should offer comprehensive information on Institutional Science and research programmes for public dissemination, while aiding coordination and oversight of these scientific activities across the research institutions. That will help build transparency, understanding and in the long-term the much-needed trust.

In this context, may I express my appreciation for this continuing initiative of the FARC started in 1995, that is precisely providing this unique forum for the dissemination of research information, a key element and mechanism of effective technology transfer. The FARC already has a Research Information System which is being further developed, including a revamped website that provides online access to information meant for all stakeholders of the agri-food community.

Distinguished Audience,
As you are surely aware, I recently made public a five-year Strategic Plan for the non-sugar sector. A year ago, I presented to the nation a Strategic Plan for the Sugar Sector. Both plans have set the direction and established a framework for developing a genuinely sustainable agricultural industry for Mauritius. We have highlighted more comprehensively the wide range of issues and questions that we have to collectively grapple with. And among these, Research & Development as well as Training will have a prominent role to play.

Just as for the sugar sector, it is our goal to transform the non-sugar agricultural sector, from a resource-based agriculture to an increasingly science and technology-based industry.
Mauritian agriculture has generally remained traditional despite numerous efforts made in the past to bring certain changes especially at the production level. However, with the present strategy of the Government to make Mauritius evolve into a knowledge and technology-based economy, the need to realign agriculture in tune with the sophistication that is taking place in other key economic sectors in the country has become most essential.

Furthermore, the survival of our export industries within the sector is also being severely threatened with stringent norms being imposed with regard to food quality. And, if the current production practices are not urgently reviewed, the possibility of retaining a competitive edge in our existing markets and of eventually being in a position to consider the development of other potential export market opportunities within agriculture would be, realistically speaking, extremely remote.

With the trade liberalisation process and the gradual elimination of trade barriers at the level of regional groupings, the local agriculture will be faced with harsher challenges. Not only will export endeavours have to face tougher competition against larger producer countries, but also, the survival of local producers would be at a threat due to the entry into our territory of cheaper agricultural products that removal of trade barriers would inevitable entail.

Taking all these threats, challenges and constraints into consideration, we realise that practical solutions lie in the adoption of modern technologies in an organised framework. In this respect, biotechnology certainly brings new hopes.

I believe that everybody in this distinguished audience would agree with me that the survival and progress within agriculture rests largely with the implementation of a proper technology based approach – acutely lacking at the production level in many small island nations and in developing states in general.

In fact, Biotechnology application in agriculture has yielded such promising and productive results worldwide in alleviating a number of recurrent constraints, that it would be unwise not to take advantage of its numerous benefits.

Biotechnology is one of the most important scientific and technological revolutions of this century and has greatly influenced various aspects of human life. The new tools of Biotechnology offer great potential for improvement in the agricultural sector, including horticultural and plantation crops as well as forest trees. Today, a vast array of the products of biotechnology are being successfully commercialised worldwide. The only aspect of biotechnology that is arousing controversial arguments from the ethical point of view and has been fuelling heated debates around the world is that pertaining to Genetically Modified Organisms (GMOs), and this is where vigilance needs to be exercised and legislative precautionary measures taken. Researchers and scientists will have to assume their responsibilities fully.

It is in this perspective that our proposal to significantly boost our Research, Training and Development capacity and improve the cost-effectiveness of our research expenditure should be viewed. The forthcoming setting up of the Mauritius Agricultural Biotechnology Institute and the proposed Food Technology Laboratory should help to address the challenges I have just highlighted and boost our capability to anticipate and prepare ourselves to fully meet challenges and seize new opportunities.

The Mauritius Agricultural Biotechnology Institute will serve as a research focus for all activities in Biotechnology and will act as a good interactive interface between academic, research and product development platforms. It will operate through a critical mass in terms of human resource capacity and equipment that it will be endowed with. The legislative framework to sustain the activities of the Institute is being established. The Genetically Modified Organisms Bill is being finalised at the level of my Ministry. A training programme in biotechnology has been devised simultaneously in order to cater for the need to provide for adequately skilled technical manpower resources once the Institute becomes operational.

There is another related measure I would like to mention here. It relates to the facility my Ministry plans to create to support in-situ and ex-situ conservation of genetic resources through the creation of the Gene Bank.

The conservation of genetic resources for food and agriculture forms an integral part of any sustainable agricultural strategy. Failure to conserve resources limits gene pools, the sources of the raw materials that breeders use to develop new varieties or improved breeds necessary to respond to changes in climate, the impact of pests and diseases, or consumers’ needs.

Your help is therefore also needed to raise public awareness of the importance of conservation and sustainable use of genetic resources.

One last point I wish to emphasise. It would be highly desirable to have more involvement of the private sector in non-sugar agricultural research. Forthcoming legislative reinforcement measures should offer the conducive environment for this involvement to materialise. There is going to be a
strengthening of IPR for biological and agricultural innovations and inventions. These include protecting plant breeders’ rights for new plant varieties through the upcoming Plant Breeders Bill. And the clustering of institutions and stakeholders as mentioned in the strategic plan should help improve institutional performance and transparency and should attract more private sector participation.

In conclusion, I would hope that relevant policy-driven research requirements be satisfied through good and unbiased agricultural research. This should be the bedrock for policy-decision making. Please keep the momentum of meetings such as this one to give fresh impetus to our common goal, that of a sustainable agricultural industry.

I understand that the keynote address to be delivered by Dr. Gabrielle Persley will pay tribute to late Zeel Peerun, whose contribution in the field of Plant Breeding at the MSIRI has been significant. I associate myself with this initiative to convey to members of Zeel’s family our appreciation and recognition of his achievements in the field of agricultural research and in politics as well.

I now have the pleasure and privilege to declare this Meeting open.

Thank you
TRIBUTE TO Z PEERUN 2003

Dr Jean Claude Autrey
Director, MSIRI

Honourable Pravind Jugnauth, Minister of Agriculture, Food Technology and Natural Resources
Excellencies of the Diplomatic Corps
Dr Gabrielle Persley, World Bank Consultant in Biotechnology
Mrs S Hanoomanjee, Permanent Secretary, Ministry of Agriculture, Food Technology and Natural Resources
Dr Teeshan Bahorun, Chairman of the Food and Agricultural Research Council
Mr Jairaj Ramkissoon, Director of the Food and Agricultural Research Council
Mr Georges Leung Shing, President of the Chamber of Agriculture
Prof Goolam Mohamedbhai, Vice Chancellor of the University of Mauritius
Distinguished Guests
Ladies and Gentlemen
Colleagues

A special word of welcome to Shani and Richard Peerun and other members of the Peerun family, and a special thought for Beti Peerun, who is in London waiting for the birth of her first grandchild.

A little more than three years ago, on 23 March 2000, the whole nation of Mauritius was shocked and saddened at the news of the passing away of Honourable Mohammad Zeelanee Peerun, Member of the National Assembly. Even the few who knew that he was undergoing medical treatment in Réunion were surprised by his sudden demise. During the last months of his life, he had, faithful to his principles, shown great courage to face the illness that finally took him away.

From all quarters of the country, including Government and the opposition, came unanimous praise of his qualities as a man, a gentleman I should say, and a politician, not that these qualities are mutually exclusive, and the values which governed his entire life. Little was however said about his career as a scientist and may be it is a unique opportunity today to address, if not redress, this situation.

Zeel Peerun, as he was commonly called, was born in 1939 in the village of Médine Camp de Masque in the East of Mauritius where he went to the primary school. He received his secondary education at the Islamic College and the Royal College of Curepipe before reading for a BSc Honours Degree in Agricultural Botany at the University of North Wales at Bangor where he graduated in 1967. Dr Marshall, his lecturer, spoke of him as “a most conscientious student who was outstanding in comparison with other overseas undergraduates that I have taught.” His stay at Bangor was going to mark his life for ever. This is where he met and married Beti, while his other encounter, a little later, was with a Mauritian student by the name of Paul Raymond Bérenger. They probably did not know then how far their life and destiny would be tied together until the very end in March 2000.

Zeel Peerun, I should say, had two careers: one as a scientist the other as a politician and both were under many aspects intertwined. Upon his return to Mauritius, Zeel took up a post as Horticulturist at the Ministry of Agriculture and also became an active member of the Club des Etudiants Mauriciens, and a founder member of the Mouvement Militant Mauricien in 1969.

In 1970, after signing the anti Banda petition he lost his job. Here I must stress that in spite of having been told that he would be sanctioned he did not remove his name from the list of signatories and accepted the consequences in order to live up to his values. This was the beginning of a long list of events where he would show that he was a man of principles and that nothing would deter him de la voie qu’il s’était tracée.

After one year out of job, during which he reverted to his horticultural training to earn a living for example by selling grafted citrus plants and other species, he was recruited at the MSIRI to work as Agronomist for the general improvement of maize which had just been included in our mandate as part of the Food Crops Diversification Programme. He collected the various local ecotypes which were eventually used in the maize hybridization programme. In September 1972, Zeel Peerun was...
redeployed to the Plant Breeding and Biometry Department as Assistant Cane Breeder, and became Scientific Officer in July 1978 when he was appointed officer in charge of the Department which is to be recalled is responsible for one of the main thrusts of the R&D programme of the Institute. For five years between 1978 and 1982 Zeel Peerun was actively involved:

- In the interspecific programme for the widening of the genetic base of sugar cane varieties, a matter of vital importance.
- In research for improving crossing and selection techniques.
- In the breeding and selection of sugar cane and eventually in the release of a number of popular commercial varieties.

He worked in close collaboration with late René Hermelin for the development of a defuzzing machine for the production of clean sugar cane seeds. This device is still in use today and has been copied by sugar cane breeders using defuzzed seed in various parts of the world.

He was also a major contributor to the production of the first catalogue on “Sugar cane varieties in Mauritius: a botanical description”, edited on the occasion of the 350th Anniversary of the introduction of sugar cane into Mauritius and dedicated, [I quote], “to those who during the 350 years have struggled to ensure the success of the sugar industry of Mauritius”, [unquote].

Zeel Peerun is the author of several scientific papers published locally and internationally, with such titles as “The effect of environment and time of harvest at early stages of selection in sugar cane”.

His professional activities did not prevent him from finding time to stand up as candidate in 1976 in the Moka-Quartier Militaire constituency but he was not returned.

Following the general elections in 1982, his life took another dimension when he was appointed High Commissioner of Mauritius in Canberra for which he was granted a five-year leave by the Institute. He took his assignment, I should say, at heart and I remember how frantically he collected documents at the Institute in order he said to put to use his new responsibilities to the advancement of Mauritius with a special attention to the MSIRI projects. Unfortunately, his assignment did not last long as again on a matter of principle he chose to resign in 1983. His request to resume duty with the MSIRI was turned down and it was only after an out of court settlement with lengthy and complex discussions that he resumed his post in 1987. This four-year period was probably the most difficult part of his life as he had to earn his living while Beti was giving birth to Shani and Richard, present in our midst. He used his horticultural and agricultural talents to earn a living. However, in spite of the hardness of times he did not become bitter and he told me that being engaged in production allowed him on one hand to bridge the gap between academia and real agricultural life while, on the other hand, enabled him to conceive agricultural development plans for the country.

Between 1987 and 1990 Zeel Peerun was back in the Plant Breeding Department while also pursuing his political life as municipal councillor of Quatre Bornes, office he held in fact between 1983 and 1991, and after the general elections of 1987 he joined the national assembly under the best loser system having run in the Montagne Blanche-Grande Rivière Sud Est constituency.

In 1990, given his talents as great communicator, Zeel Peerun was appointed Scientific Liaison Office of the Institute, post he held until his retirement in 1999. In this capacity, he reinforced the communication between the Institute and its various publics not only at the local level, but especially at the international one. He made it a duty to welcome all our guests and trainees, especially foreign ones, and he was thus a competent and motivated ambassador of the Institute. No doubt his spell in diplomacy in Canberra, however short it had been, had provided him with a great asset in his new post.

One of his achievements was also the preparation of the first ever Corporate Plan of the Institute spanning over the period 1998-2003, as a member of a small four-member team, including Mr Brian Jamieson. He was enthusiastic about this plan and spent long hours on its write up. The Institute has, on many occasions, been congratulated on the quality, contents and presentation of this document. He showed special interest in the human resource development programme of the Institute, especially the performance appraisal system, for which he made valuable suggestions which in fact were incorporated in the system which was eventually adopted and is still in use today. He was also pursuing his political career while being Scientific Liaison Officer and he was elected in 1991 and 1995 in the same constituency. He was appointed Government Chief Whip in 1996, a post he served elegantly and tactfully and his talents as diplomat were put to contribution to that end.
In the latest years of his professional life, he was interested in pursuing a career in training, a fact which is not really known, and to fulfil his wish the Institute sponsored his participation to the 21st International Course on Vocational Education and Training in Agriculture, held in Fribourg, Switzerland, in August 1998. He thoroughly enjoyed his stay in Switzerland and submitted a comprehensive report on follow up actions of value to the Institute and to the country.

Zeel Peerun retired in May 1999 having reached 60 on the 1st of May. I was particularly honoured when I was asked to propose a toast to him on his birthday in the presence of his intimate friends, including the present Prime Minister, the Deputy Prime Minister and his relatives.

Throughout his career at the MSIRI, Zeel Peerun contributed to its advancement both in the scientific and administrative fields. He was appreciated and esteemed by his colleagues at large and was particularly popular among our manual workers.

Zeel was a perfect gentleman who would never lose his temper which was quite an asset for his political career also. He was a man of consensus and was particularly careful not to hurt friends and adversaries alike. This trait of his character was probably tied to his love for nature. Zeel was very close to nature as he liked walking, fishing and hunting. He was good company and there was no trace of bitterness in him in spite of the very adverse events that he had gone through. He was serene and, I would say, il était resté lui même.

When Zeel Peerun passed away he was referred to by Honourable Navindranath Ramgoolam, then Prime Minister, in his official eulogy at the National Assembly, [I quote] “those who knew Mr Peerun will remember him for his political engagement but above all for his good manners, his modesty, his amiability and his self-effacing nature. To me he epitomized the qualities of this rare breed, the perfect gentleman.” [Unquote]. The then Leader of the Opposition, Honourable Paul Raymond Bérenger, stated, [I quote] “c’est une grande perte pour le MMM et pour le pays et c’est un ami, un vrai, qui s’en est allé. Loyalité et courage, les deux mots qui me viennent à la bouche pour décrire le grand militant qui vient de nous quitter. Sa loyauté était d’abord …. envers son idéal de société, ses principes, ses idées politiques. C’était l’honnêteté et la moralité en politique. Son courage tranquille, il l’exerça en toutes circonstances mais surtout au moment les plus difficiles. C’était la force tranquille à la mauricienne.” [Unquote]. Our present Prime Minister, Honourable Sir Anerood Jugnauth said of Zeel Peerun, [I quote], “J’ai le souvenir d’un homme idéaliste qui voulait servir son pays. Avec cette disparition je perds un ami et un frère militant, un militant de la première heure que j’ai eu l’occasion et l’honneur de cotôyer à différents moments de notre combat.” [Unquote].

I stated earlier that his studies in Bangor had marked Zeel Peerun for life. This is where he met Beti who was going to be by his side in difficult and well as in plain sailing times. With her intelligence, sensibility, and self-effacing nature, Beti is the perfect being whom Zeel had chosen for sharing his life. Beti managed to grasp all the subtleties of the Mauritian family, political and social life. Her whole-hearted support for Zeel allowed him to live by his ideals and principles. We are grateful to the circumstances which allow us, this morning, to pay tribute also to Beti who, in some say, has been overlooked when one reads all the official testimonials which were published three years ago. A few weeks ago she told me how Zeel had looked forward to being a grandfather, which he would have been these days and by coincidence, probably today.

I could talk for hours on Zeel Peerun as his multi-faceted character and his various charismas are a source of inexhaustible inspiration. I am sure, however, that if I did so I would have made an offence to his discretion and humbleness. May I conclude in saying simply that he is an example to the Mauritian nation at a time when we are tempted and surrounded by so many false values which I would not dare enumerate. He represented the true values of loyalty, courage, honesty, sincerity, friendship, idealism and patriotism in which all of us, especially our youth, should find enlightenment.

Thank you for your attention.
Science is a creative enterprise. It combines the exploration of the natural world with the generation of knowledge and its use in human endeavours. This combination of creativity with purpose is exemplified in the field of biotechnology. But the power of the new discoveries in genetics also raises concerns in many societies as to the ethics and safety of their use, and the risks they may pose to human health, biodiversity and the environment.

This overview, commissioned by the International Council for Science (ICSU) analyses the findings of a selection of approximately 50 science-based reviews, published in years 2000-2003, on modern genetics and its applications in food and agriculture and the environment. These reviews, which have been commissioned by national academies of science, governments, international organizations and private agencies on various aspects of modern genetics have mobilised considerable scientific expertise worldwide to examine the issues in both breadth and depth. However, a comparative assessment of their conclusions has not, until now, been performed.

The purpose of this analysis is to consider what are the issues that concern various societies, and, on the basis of the science underpinning the discoveries in modern genetics, what are the areas of commonality, what are the areas of divergence and differing perspectives, and where are the gaps in knowledge that may be able to be addressed through additional research. The ways in which scientific knowledge is communicated and influences public perceptions and policy choices about new technologies are also considered.

**Key Questions**

Many applications of modern genetics are being used to improve the efficiency and sustainability of present agricultural practices, in both industrial and developing countries, and there is potential for their wider use. Important applications include improving the efficiency of plant and animal breeding by enabling the use of molecular markers for early generation selection of key traits; developing molecular diagnostics for the identification and improved control of pests and diseases; and more effective diagnostics and vaccines for the control of livestock and fish diseases.

Although this review considers new genetics in the broad sense, specifically, in relation to genetically modified foods, this study poses five key questions:

- Who needs them?
- Are they safe to eat?
- Will there be any effects on the environment?
- Are the regulations adequate?
- Will they affect trade?

Definitive answers to many of the complex issues underlying these simple questions are not yet available. However, there is a growing scientific consensus around many of these issues and on the areas where further data, information and actions are most needed.

**1 Demand: Who needs genetically modified foods?**

There is a continuing demand for more, cheaper, and/or better quality food worldwide. The relative importance of these factors varies within and between societies. Poor people need better access to AMAS 2003. Food and Agricultural Research Council, Réduit, Mauritius.
more food. Those who are more affluent place more emphasis on the quality of food, in terms of appearance, variety and nutritional content.

Projections by FAO and IFPRI on the future demand and supply of food necessary to keep pace with population growth and changing dietary habits until 2020, predict increasing global demand for food. For example, cereal production for food and feed needs to increase by 40%, while livestock production needs to double, to meet increasing demand for milk and meat by year 2020. Also, land available for expanding agriculture is decreasing and water is an increasingly scarce resource. Thus, more food needs to be produced per unit available land, per unit water.

New developments in genetics need to be assessed as to their potential to contribute to the production of more, cheaper, and/or better quality food, in different situations, produced in ways that are more environmentally sustainable, when compared with present agricultural practices and other technology options.

2 Are GM foods safe to eat?

Presently available genetically modified foods are safe to eat. Food safety assessments by national regulatory agencies in several countries have deemed presently available GM foods to be as safe to eat as their conventional counterparts and suitable for human consumption. This view is shared by several inter-governmental agencies, including the FAO/WHO Codex Alimentarius Commission on food safety, which has 162 member countries, the European Commission (EC), and the Organization for Economic Cooperation and Development (OECD).

Further, there is no evidence of any ill effects from the consumption of foods containing genetically modified ingredients. Since GM crops were first cultivated commercially in 1995, many millions of meals have been made with GM ingredients and consumed by people in several countries, with no demonstrated adverse effects.

Although presently available GM foods are considered safe to eat, this does not mean that risks do not exist as more foods are developed with novel characteristics. There needs to be continuing evaluation of emerging products to ensure that new foods coming to market are safe for consumers. Food safety evaluation needs to be undertaken on a case-by-case basis. The extent of the risk evaluation should be proportionate to the possible risks involved with particular foods.

There are also benefits to human health coming from GM foods. These include: Direct health benefits such as:
- Improving nutritional quality of specific foods (eg modifying starch content in barley; oil content in rapeseed; vitamin content in rice);
- Removing allergens and/or toxic compounds from certain foods (eg peanut).
- Indirect health benefits come from changing agricultural practices, such as:
- Pest tolerant crops able to be grown with lower levels of chemical pesticides, resulting in reduced chemical residues in food, and less exposure to pesticides;
- Disease resistant crops with lower levels of potentially carcinogenic mycotoxins.

3 Will there be any effects on the environment?

Agriculture affects the environment. New genetic technologies used in agriculture will affect the environment. Their environmental effects may be either positive or negative. They may either accelerate the environmentally damaging effects of agriculture, or they may contribute towards more sustainable agricultural practices and the conservation of natural resources. It is a matter of application and choice.

The environmental effects will depend on the specific genetic application, the agricultural system and the environment (agro-ecosystem) in which it is used. Environmental impact needs to be assessed on a case-by-case basis, taking account of specific risk factors. The environmental effects of specific technologies may be either direct effects of a specific trait/species combination on biodiversity, habitats, landscape, and/or other components of the environment; or they may be indirect effects,
resulting from changing agricultural practices leading to more, less or different use of pesticides or herbicides, and/or changing land uses.

In assessing direct and indirect environmental effects, new genetic technologies need to be compared with present agricultural practices, and other technology options. Comparison with base line ecological data is also desirable, but is difficult to obtain in many instances. Also, both the risks and the benefits of new technologies need to be considered, so as to develop a picture of the options available and the choices implied.

For example, in assessing the potential for direct environmental effects of plants, the factors that need to be taken into account are the potential for gene flow from the crop plant to wild relatives to form hybrids that survive and may cause environmental damage; the potential of the plant to become a weed in cultivated fields or to move outside the field to become an invasive species in other habitats; possible effects of specific traits on non-target organisms; and unexpected effects resulting from unintended genetic recombinations. These risks are similar in kind for any plants released into the environment. Genetically modified plants that carry particular traits (e.g. pest resistance) need to be assessed for the effects that the particular trait may have on these risk factors.

In terms of direct effects, gene flow is an issue where crops are being cultivated in areas where there are wild relatives with whom they can cross in nature, in their centres of biological diversity. The ecological issue is not so much that it happens (as pollen does move in the wind and on insects, and some outcrossing occurs naturally in open-pollinated species), but does it matter? The answer to the latter question depends on whether a novel trait is introduced into a wild species that increases the fitness of the resulting hybrids to survive and become environmentally damaging themselves (e.g. to become a weed or an invasive species). Experimentally, modelling based on biological and geographic data may be useful to predict the likely behaviour of different species in various environments, near or distant from their centres of diversity.

The presently available evidence suggests that genes can move from GM crops into land races and related wild species at low frequency in areas where there are compatible wild relatives but there is no evidence of any deleterious environmental effects having occurred from the trait/species combinations presently available.

In terms of indirect environmental effects due to changing agricultural practices, most genetically modified crops presently used commercially have been modified for either insect resistance and/or herbicide tolerance. Insect resistant crops need to be used within an integrated pest management (IPM) system, so also to avoid the boom/bust cycles associated with the build up of resistance in the pest population. There are some concerns as to whether IPM systems can be used effectively with GM crops in the developing world.

Several studies have shown that the use of pesticides on cotton has declined globally by about 14% since the introduction of Bt cotton in the mid 1990s. Country studies in Australia, China, South Africa and the USA show pesticide reductions of 40-60% on GM cotton crops. The reduction in pesticide use is accompanied by an increase in the number of beneficial insects amongst the crop-associated biodiversity. Herbicide tolerant soybean has been shown to increase the efficiency of weed control and reduce soil tillage, with consequent benefits for soil conservation.

In the future, other environmental effects may result from the emerging scientific developments in the ability to modify crops with complex traits that are controlled by multiple genes (e.g. tolerance to salinity or drought). This may enable agriculture to extend into presently marginal lands and/or threaten fragile environments. For example, saline tolerant rice may be able to be cultivated in areas presently important as mangrove habitats. Drought tolerant maize could increase water use efficiency in semi arid regions of the world. The risks and benefits of such applications highlight the need for case-by-case environmental impact assessments of specific applications in different agro-ecosystems.

Future land use: One of the future challenges is devising ways and means, including standards, to enable proponents of different forms of agriculture to be able to live together in areas of multiple land use. This is particularly challenging for farmers practising broad scale agriculture and/or organic agriculture. For example, research commissioned by the EC over the past 15 years is giving guidance on ways to minimise gene flow from crop to crop and from crops to wide relatives in Europe. Unwanted gene flow can be minimised by spatial and temporal barriers between crops); by selecting

crops with low risks of gene flow outside the crop, either because they are not outcrossing species, or there are no related or wild species in the vicinity; and/or by targeting gene expression to certain parts of plants by the use of tissue specific promoters.

4 Are the regulations adequate?

There is broad agreement that regulatory systems need to be science-based, transparent, and involve community participation, and that safety assessments should be undertaken on a case-by-case basis, using the best available scientific techniques.

Regulatory processes also need to be sufficiently flexible and robust so as to be able to detect early warning of changing circumstances. Recent instances of food safety problems in several countries highlight the need for continuing vigilance in ensuring that foods brought to market are safe to eat, irrespective of their source and production methods. These foods may come from conventional or subsistence agriculture, organic agriculture and/or the cultivation of GM foods and crops.

The products of modern genetics in agriculture are regulated more stringently than their counterparts coming from traditional breeding programs or the products of other production systems such as organic agriculture.

Regulatory systems for the applications of modern genetics in food and agriculture are based broadly on assessing the safety for human health and the environment of either the product or the process by which it is produced, or a combination of the two approaches. Although the data sought by regulators is similar, their interpretation in risk assessment and management differs amongst countries and regions, particularly in dealing with areas of uncertainty.

The substantive differences come as to the level of risk regulators consider will be acceptable for a given society. Since biological systems do not deliver certainty, zero risk for any new technology is an unattainable standard: Hence the importance of risk/benefit analysis on a case-by-case basis.

Most regulatory systems agree on the need to continually improve risk assessment methods, making use of new scientific developments, so they keep abreast of emerging products and processes. Regulatory systems also need to be sufficiently flexible so as to respond to accumulating experience in the behaviour of new products once they are in widespread use.

Improving food safety assessments: There is a need for continued development of food safety assessments methods, so as to assess the safety of future products that may be the result of more complex genetic modifications (e.g. foods with modifications to their nutrient content). These scientific developments will also enable better monitoring of any unintended changes in the content of foods that may result from genetic modification. Such changes may occur either by conventional breeding or gene technology.

Improving environmental assessments: One of the areas where there is most debate is on the methods used to assess environmental impact, and on what constitutes an adverse environmental impact. One approach is to compare GMOs with organisms produced using more traditional breeding techniques. Some of the outstanding issues in assessing environmental impacts are the lack of reliable base line data, the relevance of extrapolation from small to large scale use, and from the laboratory to the field, ability to detect rare events within a relatively short experimental time scale, lags between introduction and manifestation of environmental impacts and the lack of knowledge about the complexity of ecosystems, including soil ecosystems. Assessment of the impacts of GMOs on non-target organisms need to reflect the complexity of different environments, and the need for comparison with other agricultural practices, such as pesticide use and IPM systems.

International harmonization of regulations: FAO / WHO provide an intergovernmental forum through the Codex Alimentarius commission where international agreement on standards for food safety, including GM foods can be reached. A similar forum is needed to facilitate international agreement on standards for assessing the environmental impacts of gene technology. The Cartegena Protocol of the Convention on Biological Diversity (CBD) provides an inter-governmental forum amongst the parties to the convention for assessing the impacts of living modified organisms (LMOs) on biodiversity, one component of the environment. A broader forum is needed to enable the development of
internationally agreed standards for comprehensive environmental impact assessments of the risks and benefits of new genetics in agriculture.

Costs and benefits of regulation: The cost, complexity and uncertainty of regulation in new genetics in food and agriculture is making regulatory requirements one of the barriers to entry for public research institutes, poor countries and small companies. This has long been the case in the pharmaceutical and agro-chemical sector and is becoming the case in the seed sector as well. One of the effects is that future investments are likely to concentrate even more on those products with potential commercial value where the cost of regulation can be built into the price of the product. Less investment will be available for generating public goods, including those that may be useful in emerging economies. Regulatory requirements are limiting the choices for the use of new genetics to improve agriculture in emerging economies.

There remains a lack of public confidence in the regulatory systems in some countries and this is one of the drivers behind the increasing stringency of regulation. This raises the issue of what more needs to be done to improve public confidence in the regulatory and post-approval stages of the release of genetically modified organisms into the environment.

Further science based case studies that compare the risks, benefits and regulation of crops developed through new genetic technologies with similar crops cultivated under intensive agricultural practices and/or organic agricultural practices, would be useful to illustrate the relative merits of different approaches and various scenarios.

5 Will they affect trade?

Trade implications of new technologies are becoming increasingly important. There is a need for science-based, internationally agreed standards to enable trade in genetically modified foods and commodities. The lack of clarity in this area is affecting not only the major agricultural exporting countries, but is also causing policy makers in developing countries to hesitate as to their domestic policies on food and agriculture in case the use of new genetics technologies may put at risk future markets. This will be a major issue in the forthcoming world trade negotiations. The World Trade Organization and the United Nations agencies have major roles to play here as standard setting bodies, to help resolve these issues.

Future Perspectives

The science underpinning developments in modern genetics is not informing the public in a manner commensurate with the volume and quality of the scientific data and analysis available. The scientific community could play a more active and better organized role in raising public awareness about emerging genetics and what it means for different societies, in terms of choices, risks and benefits.

Additional, publicly funded research that addresses key gaps in present knowledge would be valuable to inform the debate about the use of modern genetics. The value of this research may be increased if the key questions are framed in an “authorising environment” that reflects the concerns of the public, policy makers and politicians, nationally and internationally.

In the regulatory area, additional research is necessary to assist in the continued development of regulatory approaches that keeps abreast of new scientific developments. For example, there is a need for the continued development of food safety assessment methods, to deal with emerging products such as nutritionally enhanced foods and other complex traits controlled by multiple genes.

There is also a need for the development of internationally agreed standards for the assessments of environmental risks and benefits of genetically modified organisms. Much data has been generated over the past decade on the behaviour of genetically modified organisms in various environments. It would be helpful to guide future regulatory decisions if more of this data was made publicly available.

The broad range of applications in modern genetics in agriculture could contribute more towards improving the efficiency and sustainability of agriculture in emerging economies. Currently available applications of new genetics could improve the efficiency of plant breeding; develop new diagnostics
and vaccines for the control of pests, parasites and diseases in crops, trees, livestock and fish; and generate disease-free planting material, with substantial increases in productivity.

*Genetically modified crops* also offer promise to contribute more towards *food security and poverty reduction*. New varieties of crops with useful traits may result from public or private investments or, increasingly through public/private partnerships, which offer much promise for addressing the problems in emerging economies in which private companies would not normally invest.

*The successful deployment of new products will require public acceptance of new products; an enabling policy and regulatory environment, including safety assessments and intellectual property management; investments in research and development; and local private sector development for distribution and marketing of seeds and other new products.*

**Further Information**
The complete documentation for the study is available from ICSU. For further details see [www.icsu.org](http://www.icsu.org), and [www.doylefoundation.org](http://www.doylefoundation.org).
IDENTIFICATION AND CHARACTERIZATION OF PATHOGENS ASSOCIATED WITH YELLOW LEAF SYNDROME OF SUGARCANE

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ABSTRACT

Yellow leaf syndrome (YLS) of sugar cane is characterized by the yellowing of the midrib followed by the leaf blades in mature canes. Two pathogens have been associated with the disease: a luteovirus, Sugar cane yellow leaf virus (SCYLV) and a phytoplasma, sugar cane yellows phytoplasma (SCYP). Reverse transcriptase polymerase chain reaction (RT-PCR) was used to identify the virus while a nested-PCR was found to be reliable for the detection of the phytoplasma. The two pathogens were observed in sugar cane plants with or without symptoms and they also co-existed in a number of varieties. A strong correlation was found between the presence of the phytoplasma and YLS symptoms when compared to the presence of the virus. Restriction fragment length polymorphism (RFLP) analysis of the phytoplasma 16S rRNA amplified product demonstrated the presence of at least three phytoplasma groups in sugar cane in Mauritius.

Keywords: yellow leaf syndrome, luteovirus, phytoplasma, RT-PCR, nested-PCR, RFLP

INTRODUCTION

Since the late 1980s, a new disease of sugar cane, yellow leaf syndrome, has been observed in many sugar cane producing countries (Lockhart and Cronjé 2000). Affected plants show intense yellowing of the midrib, which may spread to the leaf blade followed by tissue necrosis from the tip of the leaf progressing towards the leaf base. Other symptoms include shortening of terminal internodes and accumulation of sucrose in midribs. The aetiology of the syndrome was undetermined for some time. Subsequently, a luteovirus named Sugar cane yellow leaf virus (SCYLV) was detected by Lockhart et al. (1996) and it was found to be associated with the syndrome (Vega et al. 1997). This luteovirus is an unclassified member of the family Luteoviridae (Moonan et al. 2002).

In addition to the presence of SCYLV, some evidence suggested that in South Africa, a phytoplasma named sugar cane yellows phytoplasma (SCYP) belonging to the western X group was also associated with YLS (Cronjé et al. 1998). The phytoplasma was found in sugar cane plants co-infected by SCYLV but also in samples with YLS-like symptoms in the absence of the virus (Cronjé et al. 1998).

YLS was first observed in Mauritius in 1994 on variety CP 721210. Symptoms were subsequently observed in several other varieties and the presence of SCYLV was confirmed in 1996 (Saumtally and Moutia 1997). In this study, we report the results of our investigations between 1999 to 2002. In 1999, efforts were directed to determine the causal organism(s) associated with YLS symptoms in sugar cane in Mauritius. The occurrence of SCYLV and SCYP was further assessed between 2000-2002 in commercial fields, nurseries and imported varieties undergoing quarantine. The phytoplasma was also characterized by RFLP.
MATERIALS AND METHODS

Plant material

To assess the relationship between expression of YLS symptoms and the presence of SCYLV or SCYP, 134 leaf samples derived from 116 varieties were collected from mature canes in 1999. The varieties were obtained from a closed quarantine glasshouse, variety collection plots, or commercial fields island-wide. Material taken from each stool was visually assessed for the presence or absence of YLS symptoms. Samples from each stool were taken to the laboratory and nucleic acids extracted to verify for the presence of SCYLV and SCYP. Between 2000-2002, a new batch of 157 samples from young symptomless canes derived from 67 local and imported varieties were checked for SCYLV and SCYP.

Total nucleic acids extraction

Total nucleic acids were extracted according to the method described by Harrison et al. (1994). Three grams of young fully unrolled leaf samples were cut into small pieces and finely ground in liquid nitrogen using a mortar and pestle. The powdered tissue was transferred to 15 mL CTAB extraction buffer (2% CTAB, 1.4 M NaCl, 20 mM EDTA, pH 8.0, 100 mM Tris -HCl, 0.2% 2-mercaptoethanol) pre-warmed at 65° C in a 50 mL Corning tube. The mixture was incubated at 65° C for 1 hr in a water bath, then allowed to cool for a few min. The extract was then mixed with an equal volume of chloroform:isoamyl alcohol (24:1) and centrifuged at 4000 rpm for 15 min. The supernatant was transferred to a new tube and cold isopropanol (2/3 v:v) was added and gently mixed. Total nucleic acids were precipitated after incubation at -20° C for 1 hr, then spun out using a glass Pasteur pipette. The pellet was washed twice with 70% ethanol, dried and resuspended in sterile distilled water.

For some samples, DNA was also extracted from the cane stalk as follows: a middle node was selected and the outer skin removed. The node was thinly diced, then ground in a coffee grinder using liquid nitrogen. DNA was extracted from the ground powder using the CTAB buffer as described above.

Detection of SCYLV by RT-PCR

SCYLV was detected by RT-PCR on total nucleic acids as follows: amplification was carried out using primer set YLS 462 and YLS 111 (sequences provided by Dr M Irey, US Sugar Corporation, FL, USA). The nucleic acids sample and primer YLS 462 were boiled for 5 min, quenched on ice and reverse-transcribed at 42° C for 15 min followed by heating at 99° C for 5 min. Amplification was carried out in a 25 µL reaction mixture with the following thermal cycles: 94° C 1 min, 54° C 1 min, 72° C 20 min, 1 cycle; 94° C 1 min, 54° C 1 min, 72° C 2 min, 40 cycles and a final elongation at 72° C for 10 min. RT-PCR products were electrophoresed on 1.8% agarose gels, stained with ethidium bromide and photographed under UV light.

Detection of SCYP by nested-PCR

SCYP was detected from total genomic DNA by nested-PCR as described by Gunderson and Lee (1996). Amplification was carried out on the 16S rRNA operon followed by a nested amplification of the first round PCR product. Primer pair combinations used in the first round was either P1/P7 or SN910601/P6 or R16mF2/R16mR1 (Table 1). A standard reaction mixture of 25 µL consisted of the following: reaction buffer X1 (Roche Products Ltd, South Africa-RP ), 200 µM dNTP (RP), forward and reverse primers (0.4 µM), 0.3 U Taq polymerase (RP) and total nucleic acids (100 ng). One µL of the first round amplicon was further amplified using nested primers R16F2n and R16R2 (Table 1). The PCR products were electrophoresed on 1.0% agarose gel, stained with ethidium bromide and photographed under UV light.
Table 1 Sequences of universal primers used in the amplification of phytoplasma 16S rRNA operon

<table>
<thead>
<tr>
<th>Primer</th>
<th>Sequence</th>
<th>Reference</th>
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<tr>
<td>P1</td>
<td>5'-AAGAGTTTGATCCTGGGTCCTAGATT-3'</td>
<td>Deng and Hiruki 1991</td>
</tr>
<tr>
<td>P7</td>
<td>5'-CGTACCTTCATCGGCTCTT-3'</td>
<td>Smart et al. 1996</td>
</tr>
<tr>
<td>SN910601</td>
<td>5'-GTTTGATCCTGGGTCCTAGATT-3'</td>
<td>Namba et al. 1993</td>
</tr>
<tr>
<td>P6</td>
<td>5'-CGGTAGGGATACCTTGTTACGACTTA</td>
<td>Deng and Hiruki 1991</td>
</tr>
<tr>
<td>R16mF2</td>
<td>5'-GATGCAAGTCTGAACGGA-3'</td>
<td>Gunderson and Lee 1996</td>
</tr>
<tr>
<td>R16mR1</td>
<td>5'-CTTAACCCCAATCATCGAC-3'</td>
<td>Gunderson and Lee 1996</td>
</tr>
<tr>
<td>R16F2n</td>
<td>5'-GAAACGACTGCTAAGACTGG-3'</td>
<td>Lee et al. 1993</td>
</tr>
<tr>
<td>R16R2</td>
<td>5'-TGACGGGGCGGTGAGTACGACG-3'</td>
<td>Lee et al. 1993</td>
</tr>
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RFLP analysis of PCR products

Five phytoplasmas (groups 1-5) according to the classification of Lee et al. (1993) were also amplified separately in a single step PCR using primer pairs R16F2n and R16R2. These consisted of European Aster Yellow (group 1), Faba Bean Phyllody (group 2), Peach Yellow Leaf Roll (group 3), Coconut Lethal Yellow (group 4) and European Elm Yellow (group 5). The amplified products were digested together with amplified PCR products from sugar cane using restriction enzyme Rsal. The reaction mixture (15 µL) consisted of the following: 8 µL PCR products, 2.0 U enzyme (RP), X1 reaction buffer (RP) and sterile distilled water. Digestion was carried out in a water bath at 37º C for 3 h, then denatured for 5 min at 65º C. Digested products were separated by electrophoresis on 6% polyacrylamide, stained with ethidium bromide and visualised under a UV transilluminator. RFLP profiles of samples were compared with the five phytoplasma groups.

Characterization of RFLP groups

Transformation of E. coli

R16F2n/R16R2 amplified products from three samples showing different Rsal RFLP profiles were selected as inserts. The three different samples were denoted as sample B (amplified from DNA extracted from stalk showing a mixed group 3 and 4 RFLP pattern), sample C (from DNA extracted from leaves with group 3 specific pattern) and sample D (from DNA extracted from stalk showing a group 1 profile). PCR products were ligated into linearised pGEM-T Easy vector (Promega) and cloned into competent E. coli cells according to the method described in Promega Technical Manual 042. Each transformation culture (100 µL) was then plated in duplicate onto LB/ampicillin/IPTG/X-gal plates. The plates were incubated at 37º C overnight until the appearance of white/blue colonies.

Detection of inserts from transformed colonies and RFLP analysis

PCR reaction mix (25 µL) with primers R16F2n/R16R2 was set up as described by Gunderson and Lee (1996). Individual white colonies were scraped using a sterile toothpick and transferred into PCR tubes and the insert amplified. PCR products were run on 1% agarose gels. Positive PCR products were digested with Rsal, separated on 2% agarose and 1% Metaphor™ gel and RFLP profiles compared with those of phytoplasma groups 1-5.

RESULTS AND DISCUSSION

In 1999, among the 134 samples representing 113 varieties obtained from mature canes, 63 (54 varieties) were positive for the phytoplasma. A positive sample produced the expected 1250 bp fragment of the phytoplasma 16S rRNA gene after nested-PCR using primers R16F2n and R16R2.
There was a positive significant correlation ($r = 0.36$) between the presence of the phytoplasma and YLS symptoms in the cultivars tested. Using RT-PCR, SCYLV RNA was amplified from 100 samples representing 82 varieties. The expected fragment size of 352 bp was amplified with primers YLS111 and YLS462 from both symptomatic and asymptomatic samples. Of the 100 SCYLV infected samples, 59 expressed YLS symptoms and 41 were symptomless. The association of symptoms of YLS with the presence of SCYLV was non-significant ($r = 0.09$).

**Figure 1** RFLP profiles of PCR products amplified with primers R16F2n/R16R2 following digestion with *RsaI* and separation on 6% polyacrylamide. Lanes 1-5: phytoplasma belonging to groups 1-5, lanes 6-12: sugar cane samples A-G and lane L: 100 bp ladder.

Between 2000 to 2002, a new batch of 157 samples representing 71 additional local and imported varieties was tested for the two pathogens. The phytoplasma was found to be present in 26 cultivars while the virus was detected in 34 of them. From 1999-2002, out of a total of 174 varieties tested, 80 were found infected with SCYP and 116 with SCYLV.

Our results demonstrated that both SCYLV and SCYP are present in Mauritius. The survey also showed that SCYLV is more widely distributed than SCYP in local and imported varieties of sugar cane with 67% incidence. However, a strong correlation between presence of YLS symptoms and SCYP was noted. These results are in agreement with those described in South Africa and in Cuba (Cronjé et al. 1998, Arocha et al. 1999) where SCYP was significantly correlated with YLS symptoms. However, association of symptoms to infection is not an efficient means for disease diagnosis since yellowing of leaves is also dependent on cane variety, growth stage and environmental stress conditions such as drought.

Digestion with *RsaI* of the nested-PCR product generated by primers R16mF2/R16mR1 for the first round followed by primers R16F2n/R16R2 for the second round gave four distinct RFLP profiles. Comparison of the restriction pattern with the five phytoplasma groups of Lee et al. (1993) showed that four groups namely group 1, group 3, group 4 and a combination of groups 3 and 4 were present (Figure 1). PCR products from the different groups except for the one showing group 4 pattern were selected for cloning into *E. coli*. To check for the integrity of the inserts, nine amplicons (three transformed colonies per sample) were digested with *RsaI* and their profiles compared with those of groups 1-5 phytoplasmas. The profiles obtained are shown in Figure 2. Restriction digest of PCR products from colonies of the group 3 was identical to the insert.
Identification and characterization of pathogens associated with sugarcane yellow leaf syndrome. Y Parmessur et al.

Figure 2 RFLP pattern of transformed colonies digested with Rsal showing the existence of two operons from sample with a mixed group 3 and group 4 pattern (lanes 2-4 & lanes 8-10). Lane 1; 100 bp ladder, lanes 5-7; profile produced with group 3 specific pattern, lanes 11-15; phytoplasmas of groups 1-5, lane 16; undigested PCR product and lane 17, 123 bp ladder

For the sample with a mixed pattern of groups 3 and 4 (consisting of four bands), after cloning and restriction enzyme digestion of inserts from the three colonies, the existence of two types of 3-banding patterns were observed. Insert from one colony gave a group 3 pattern while from the remaining two colonies, a group 4 pattern was obtained. These results may suggest the presence of two operons within the same phytoplasma. These are amplified independently by the same primers, co-migrate on agarose gel and show a combined RFLP pattern upon digestion. Through cloning, each fragment was transferred to a different E. coli cell, each showing a different restriction pattern. The existence of two strains of phytoplasma, each belonging to a different group, within the same plant is also a likely explanation. Two colonies with inserts from the typical group 1 (three bands prior to cloning) maintained a similar RFLP pattern of the group upon digestion with Rsal. However, one colony produced two new fragments of 170 bp and 260 bp while a larger fragment of 430 bp disappeared. A point mutation within the latter band may have led to the formation of a new Rsal restriction site leading to the disappearance of this band and the appearance of two additional smaller bands. These results further add to the diversity of phytoplasma present in Mauritius.

CONCLUSION

In this study, the detection of SCYLV and SCYP by RT-PCR and nested-PCR were optimized and these tests are now routinely used to screen both local and imported varieties. Our survey has shown that both pathogens are widely distributed in Mauritius but with a higher occurrence of SCYLV. However, a significant correlation was observed between presence of the phytoplasma and symptoms. Much diversity was also observed amongst the strains of SCYP in Mauritius. Using RFLP, at least three different phytoplasma groups were observed. The cloning of the partial 16S rRNA gene followed by analysis of the inserts by RFLP demonstrated the existence of more than one phytoplasma strain in a plant sample or the existence of dual 16S rRNA operon within the same phytoplasma. This confirms previous reports from C Cronjé and R Davis (personal communication) of mixed strains of phytoplasma in sugar cane varieties. Further analysis of sequences of the various phytoplasma groups should provide an insight of their genetic relationship.
ACKNOWLEDGEMENTS

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REFERENCES


IN VITRO REGENERATION OF ASPARAGUS OFFICINALIS: PRELIMINARY RESULTS

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ABSTRACT

Indirect organogenesis and somatic embryogenesis were used for the in vitro regeneration of Asparagus officinalis. For the organogenesis pathway, nodal explants were treated with different NAA and BAP concentrations for both callus induction and shoot development. It was observed that both NAA and BAP should be present in the medium to induce callus formation followed by organogenesis. The treatment inducing the formation of the highest number of shoots (mean shoot number per explant = 20.5) was the one containing 0.015 mgL⁻¹ NAA and 0.5 mgL⁻¹ BAP. The effect of two IBA concentrations (1.0 and 1.25 mgL⁻¹) on rooting of regenerated shoots was also investigated, with 1.25 mgL⁻¹ giving a higher rooting percentage (50%). Somatic embryogenesis was attempted on nodal and shoot tip explants in NAA supplemented MS basal media. Shoot tips were found to generate the highest number of plantlets at NAA concentration of 12 mgL⁻¹, while for nodal section a concentration of 3 mgL⁻¹ of NAA was required. The formation of somatic embryos was confirmed by histological analysis. The percentage regeneration of plantlets was highest (83.3 %) when nodal explants were treated with 0.015 mgL⁻¹ NAA and 0.5 mgL⁻¹ BAP, thereby suggesting an efficient method of regeneration of asparagus plantlets.

Keywords: Asparagus officinalis, tissue culture, indirect organogenesis, somatic embryogenesis

INTRODUCTION

Asparagus, a member of the Liliaceae family, is a dioecious perennial producing edible spears or growing stems (Plate 1a and 1b). It is native to the Far East and the Mediterranean regions. The asparagus crop is adapted to a wide range of climatic conditions, which explains its worldwide production (Reuther, 1984). It is a high value crop that has been grown in Mauritius for the last 20 years. As the sugar industry is suffering from great competition on the world market and due to uncertainties linked to the LOME agreements, the Mauritian government has been providing incentives to encourage agricultural diversification. Asparagus is one of the potential candidates that could be produced on a large scale because of its interesting selling price on the world market. In 2000, 35 tonnes of asparagus produced on 14.3 hectares of land (data from Agricultural Research Extension Unit - AREU) fetched an average price of Rs 180.00 per Kg on the local market. The amount of asparagus currently produced is insufficient to meet the growing demand by the Mauritius public and the tourist industry. To this effect, asparagus is being imported to meet the local needs. However, it is noteworthy that in 1995, Mauritius exported 2168 Kg of asparagus to Reunion Island at a price of Rs 120 per Kg (information provided by AREU).

Generally the revenue to the producer for the sale of one tonne of asparagus on the local market is about Rs 80,000, with a cost of production of about Rs 50,000 per tonne (Heerah, 1998). The selling price for 1 tonne of Mauritian sugar on world market was between Rs 12,000 and Rs 12,500 for year 2002, with a production cost varying between Rs 5000 and Rs 7000 for 1 tonne of sugar for that year (Personal comm., source Farmers Service Centre). These figures clearly indicate the potentiality of asparagus as a profitable crop. However, large-scale production of asparagus would only be sustainable, if an efficient rapid propagation method is devised by using technology-based approaches as spelt out in the non-sugar sector strategic plan 2003-2007.

Plate 1a  Asparagus plants growing in field (magnification: X 0.03)  
Plate 1b  Young spear of about 15 cm emerging from crown (magnification: X 0.13)

The traditional method of propagation of asparagus adopted by Mauritian growers, involves the division of the parent crown into 2-4 parts, which are then cultivated separately to give new plants. However, this form of propagation is very slow as one plant gives only 2-4 new plants per year under optimum conditions in absence of any pest invasion of injured surface (Ornstrup, 1997). One method that allows cloning of high-yielding varieties at a fast rate is micropropagation.

Early reports of tissue culture of Asparagus officinalis date back to 1945 (Loo, 1945) and since then, this sector has experienced a great deal of development. Several methods of in vitro regeneration of asparagus have been established namely: direct organogenesis (Murashige et al., 1972, Hasegawa et al., 1973 and Yang and Clore, 1973), indirect organogenesis (Reuther 1977b, 1984) and somatic embryogenesis (Takatori et al., 1968; Julien 1974 and Reuther 1977b).

Among the existing pathways of asparagus in vitro regeneration, none of them are used on a large commercial scale for propagation, as regenerated plantlets have poor survival rate either at hardening or at field level (Desjardins, 1992). This can be attributed mainly to the low and erratic rooting behaviour of some clonal selections and the inability of most regenerated plantlets to develop a crown (Doré, 1988; Thévenin and Doré, 1976). It has also been noted that most of the in vitro regenerated plantlets that survive in the field have reduced yield (Desjardins, 1992). These problems are mainly due to excessive stress suffered by regenerated plantlets during their in vitro developmental stages (Desjardins, 1992). Some important factors responsible for the low survival of regenerated plantlets are: the plant growth regulators used (as these affect formation of crown and normal roots); sugar content in culture medium (as its presence in large amounts can make the plantlets heterotrophic); and light intensity (that affects cladophyll formation which are leaf-like structures responsible for photosynthesis).

The aim of this study was to develop a method of regeneration that allows rapid formation of healthy and genetically stable plantlets that can adapt properly to our field conditions. Although several varieties of Asparagus officinalis are cultivated in Mauritius, this work was carried out on one of the most cultivated variety, “Mary Washington”. The two main pathways of regeneration that were considered were indirect organogenesis and somatic embryogenesis as they both have very high rate of regeneration.

MATERIALS AND METHODS

Culture condition

The culture environment inside the culture room was kept constant during the whole experiment (unless otherwise stated): the temperature was maintained at 25±1°C and the light intensity was 1000 Lux at daily periods of 16 hours.

**Plant materials**

Asparagus seeds (*Asparagus officinalis* – Mary Washington, Batch No. 2270-062; Technisem: France) were cultured aseptically on a basal medium of half strength Murashige and Skoog (1962) medium with 0.6% agar (oxoid number 3) and 3% sucrose, incubated at 25±1°C and under a light intensity of about 3000 Lux.

**Indirect organogenesis**

**Callus induction**

Nodal explants (length of about 4mm) from sterile seedlings were cultured on MS salts and vitamins and 3% sucrose containing different combinations of NAA (0, 0.005, 0.01, 0.015 mgL⁻¹) and BAP (0, 0.25, 0.5, 0.75, 1.0 mgL⁻¹) for 4 weeks in light condition (1000 Lux) and at a temperature of 25 ± 1°C (Table 1).

<table>
<thead>
<tr>
<th>Concentration of BAP (mgL⁻¹)</th>
<th>Concentration of NAA (mgL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>K</td>
<td>L</td>
</tr>
<tr>
<td>P</td>
<td>Q</td>
</tr>
</tbody>
</table>

Callus was induced in the petri-dishes (diameter 9cm) containing 25 mL of culture media as from the first week of inoculation. After 28 days, the explants together with their primary calli were subcultured in media of same composition in petri-dishes.

**Shoot Culture**

After 28 days, the explants from the callus induction media were subcultured in similar growth media in jam jars (500 mL capacity - containing 50 mL of medium). After 28 days, five treatments giving the greatest numbers of shoots of size 3mm or more were selected and their shoot numbers counted.

**Rooting**

Rooting of shoots from the selected treatments was tried on two different media, both containing MS basal medium with 2.5% sucrose. The two media differed only in their IBA content: containing 1.0 mgL⁻¹ and 1.25 mgL⁻¹ respectively. The regenerated shoots were placed at a frequency of 2 per jar containing 20 mL of medium. Shoots from each of the five selected treatments were used to set up four replicates for each of the two rooting media. After inoculation of shoots on the rooting media (2 shoots per jar), the jars were placed in the culture room and the rooting percentage was recorded after 40 days.

**Growth of regenerated plantlets to transplantable size**

Shoots that have rooted successfully in the rooting media were transferred to 50 mL of MS basal medium in jam jars, to allow the plants to grow to transplantable size. After a period of 30 days, the plantlets were hardened in the lab in trays containing lecca, peat and vermiculite in the ratio of 1:1:1 by volume. The trays were all enclosed in plastic bags (with few holes for aeration) to maintain high humidity level.
Somatic embryogenesis

The auxin used for embryonic calli induction was NAA and was used at 5 different concentrations in the basal medium. 25 mL of each medium was used per petri-dish. Two different explants were used: the shoot tip (1-2 mm) and the nodal section (0.4-0.6 mm) from 28 days old in vitro seedlings. Each treatment (Table 2) was replicated 4 times and was arranged in a completely randomised design. After 4 weeks, the embryonic calli that had developed were transferred to MS basal medium at a frequency of 3 per petri dish.

Table 2 Nature of explant and concentration of NAA used for the 10 treatments for somatic embryogenesis.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Explant used</th>
<th>Concentration of NAA used (mgL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>Node</td>
<td>0</td>
</tr>
<tr>
<td>N3</td>
<td>Node</td>
<td>3</td>
</tr>
<tr>
<td>N6</td>
<td>Node</td>
<td>6</td>
</tr>
<tr>
<td>N9</td>
<td>Node</td>
<td>9</td>
</tr>
<tr>
<td>N12</td>
<td>Node</td>
<td>12</td>
</tr>
<tr>
<td>N0S</td>
<td>Shoot tip</td>
<td>0</td>
</tr>
<tr>
<td>N3S</td>
<td>Shoot tip</td>
<td>3</td>
</tr>
<tr>
<td>N6S</td>
<td>Shoot tip</td>
<td>6</td>
</tr>
<tr>
<td>N9S</td>
<td>Shoot tip</td>
<td>9</td>
</tr>
<tr>
<td>N12S</td>
<td>Shoot tip</td>
<td>12</td>
</tr>
</tbody>
</table>

The second, third and fourth sub-culture were performed at an interval of 28 days on same medium, in jam jars containing 50 mL of medium. For the somatic embryos to develop fully into plantlets of transplantable size, they were repeatedly sub cultured on pure MS for 4 months after induction in auxin-rich media. Total number of complete plantlets regenerated per treatment was counted prior to hardening.

Histological analysis

Somatic embryogenesis was induced as explained above. Explants from one petri-dish were harvested after every 2 days as from the 14th day of inoculation on auxin rich medium. The explants were fixed in formalin: glacial acetic acid: 70% ethanol (2: 1: 17 v/v), dehydrated in an ethanol series and embedded in paraffin wax. Serial sections of 10 μm thickness were cut and stained with safranin/ haematoxylin combination (Doolaree, 1993)

RESULTS AND DISCUSSION

Indirect Organogenesis

Calli were induced in all of the 20 media as from 10 days of inoculation. The calli proliferated very quickly to form compact masses that ranged from pale-yellow to light green in colour (Plate 1d). Thick green shoots developed from the callus masses as from the third week of culture. After three months of culture, the five best treatments with the highest average number of shoot of size 3mm or more per explant were found to be R, S, B, Q and N (Figure 1). The results obtained show the importance of both auxin and cytokinin in callus and shoot induction in Asparagus officinalis, except for treatment B where cytokinin alone was used.

Plate 1d Indirect organogenesis – close view of pale green compact callus from which shoots are developing following 8 weeks of inoculation of explant (magnification: X3).

Figure 1 Comparison of the average number of shoots regenerated per explant from the 5 best treatments selected (selection was based on highest average number of shoot of size 3mm or more per explant)

From statistical analysis (Table 3) it was confirmed that the difference between treatment R and treatments S, B, Q and N was highly significant (at 0.5% level). However, no significant difference was found between treatments S, B, Q and N.
Table 3 Mean shoot production per explant for the five best treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean shoot Number per explant</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (0.015 NAA / 0.5 BAP)</td>
<td>20.50 a</td>
</tr>
<tr>
<td>S (0.015 NAA / 0.75 BAP)</td>
<td>6.75 b</td>
</tr>
<tr>
<td>B (0.25 BAP)</td>
<td>5.86 b</td>
</tr>
<tr>
<td>Q (0.015 NAA / 0.25 BAP)</td>
<td>4.95 b</td>
</tr>
<tr>
<td>N (0.01 NAA / 0.75 BAP)</td>
<td>2.90 b</td>
</tr>
</tbody>
</table>

(Mean separation by protected LSD at 0.5% level)

For rooting of regenerated shoots, 1.25 mgL⁻¹ of IBA was most appropriate, as shoots from the five treatments gave higher rooting percentage (50%) than with 1.0 mgL⁻¹ of IBA (36.7%). However, this has to be confirmed by statistical analysis.

According to Yang and Clore (1974a), rooting percentage increases when shoots are allowed more time on rooting media. In their studies they showed, with significant evidence, that shoots regenerated from stem segments cultured for 20 weeks had a higher rooting percentage (92.2%) when allowed to root for 8 weeks. The method used by Yang and Clore, however, involved a longer culture period, which is a major drawback. In the present study the emphasis is laid mostly on fast production of plantlets. Data obtained from Yang and Clore’s study clearly indicate that the age of the shoots and the rooting time should be optimised to increase rooting frequency.

**Indirect Somatic Embryogenesis**

The shoot tips and node sections developed embryogenic calli on the NAA supplemented media (**Plate 1c**). The histological analysis confirmed that the circular structures with masses of rapidly dividing cells at its centre (**plate 1f**) were proembryoids separating from the callus. The cells in the proembryoids had large nuclei and thin layers of cytoplasm.

**Plate 1c** Embryogenic callus observed (after 2 weeks) from nodal explant placed on auxin-rich medium – 3 mg L⁻¹ (magnification: X7)  
**Plate 1f** Proembryoid separating from callus mass - slide was prepared from NAA 3 mg L⁻¹ (magnification: X200).

In most of the treatments, shoots appeared from the embryogenic calli within a month on the somatic embryo inducing media. However, it was noted that in treatments where shoot tips were used as explants the response was quicker. When the explants together with their mass of callus were subcultured on pure MS, a higher number of somatic embryos with bipolar axis germinated to form complete plantlets. It was only upon the second subculture in the jam jars that the shoots grew longer and developed cladophylls for photosynthesis. As the plantlets regenerated at this stage were quite fragile, they were allowed to mature by repeated subculture on pure MS over a 28 days period for 2 months.

Our results (Table 4) show that the best treatment for somatic embryo production by nodal explant is N3 and that for shoot tip explant is N12S. However, statistical analysis has to be developed to confirm the observation.

**Table 4** Mean number of plantlets formed per explant per treatment (some treatments not recorded in table as they gave no response or showed necrosis)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean no. of plantlets regenerated</th>
</tr>
</thead>
<tbody>
<tr>
<td>N3</td>
<td>7.0</td>
</tr>
<tr>
<td>N6</td>
<td>2.0</td>
</tr>
<tr>
<td>N3S</td>
<td>3.5</td>
</tr>
<tr>
<td>N6S</td>
<td>3.5</td>
</tr>
<tr>
<td>N9S</td>
<td>4.5</td>
</tr>
<tr>
<td>N12S</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Most of the research on somatic embryogenesis has involved the auxin 2,4-D (Levi and Sink, 1991; Saito *et al.*, 1991; Kohmura *et al.*, 1994) to induce embryogenic calli. Although 2,4-D is considered as the most potent auxin for the induction of callus and formation of somatic embryos (Ammirato, 1983), it is also responsible for the development of abnormal structures (Levi and Sink, 1991). Thus in the present study, NAA was preferred to 2,4-D, as it has been found to produce somatic embryos with higher chances of conversion into normal plantlets (Levi and Sink, 1991). The choice of very young plant material (28 days old in vitro seedlings) for this work was made to ensure a better response (Vasil and Vasil, 1986; Thorpe *et al.*, 1991). The method of somatic embryogenesis used in the study is in line with findings cited in literature. However, the approach is original in the sense that it involved very low levels of an auxin on in vitro generated young explants.

Research carried out by Levi and Sink (1991) has shown that NAA induced embryogenic callus from in vitro crowns had a plantlet regeneration rate of 11.9 plantlets per gram of callus. In our study (Table 4), the highest number of plantlets regenerated per explant was 7, suggesting that our method of regeneration is far from optimum.

The small number of plantlets regenerated by this pathway, can be attributed to the too short exposure of the explants to the auxin-rich media. This implies an inadequate time period for the dedifferentiation process to occur. Other important factors that might have negatively affected the pathway are poor culture condition and inappropriate culture medium for growth and development of somatic embryos.

**CONCLUSION**

These preliminary results show that the treatment containing 0.015 mgL⁻¹ NAA and 0.5 mgL⁻¹ BAP gave the highest number of plantlets (Plate 1e). However, this number is still low for an efficient use in mass propagation. Nevertheless, it provides a starting point for future research on indirect organogenesis for micropropagation.

The low yield of plantlets obtained through somatic embryogenesis can be ascribed to non-optimal culture condition. This work is being oriented towards the type and concentration of plant growth regulator used both for induction of embryogenic calli and the development of somatic embryos.

Furthermore, for the potential use of any in vitro regenerated plantlets for micropropagation, it is essential to confirm their genetic stability. RAPD analysis and chromosome counting are two important tools that are currently being used on regenerated plantlets to test if they are true to type.

**Plate1e** Shoot development on treatment 0.015 NAA / 0.5 BAP, after 3 months of *in vitro* culture (magnification: X 0.12).

**ACKNOWLEDGEMENTS**

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**REFERENCES**


INDUCED MUTATION AND IN VITRO CULTURE OF ANTHURIUM ANDREANUM

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ABSTRACT

The main aims of the project were to study the tissue culture response and the effect(s) of induced mutation through gamma-ray irradiation on Anthurium, an economically important crop of Mauritius. Tissue culture studies were carried out on Nitta, Osaki and Anouchka varieties and the Nitta variety was used for the induced mutation study. Different explants were used for investigating the phenotypic and genotypic effects of three radiation treatments (5, 10 and 15 Grays / Gy) together with a control.

For the tissue culture experiments, two different media, viz modified Murashige & Skoog (1962) and Nitsch (1969) were used. Apart from the time period for callus induction, no differences in terms of regeneration were noted amongst the three varieties tested. Callus induction in all three varieties was found to be more rapid and prolific when Nitsch medium containing BA at 1 mg L\(^{-1}\) and 2,4-D at 0.1 mgL\(^{-1}\) with a reduced concentration of ammonium nitrate (200 mg L\(^{-1}\)) was used. Shoot formation occurred when BA concentration was reduced to 0.5 mgL\(^{-1}\) and the ammonium nitrate level increased to 720 mg L\(^{-1}\). Regenerated shoots rooted readily on Nitsch medium containing IBA (1.0 mg L\(^{-1}\)). Rooting was improved significantly by the addition of activated charcoal (0.04%) to the medium.

For the irradiation studies, explants treated with 5 Gy gave the best response in terms of callus formation and regeneration while the 15 Gy doses were lethal to the Anthurium tissues. The phenotypic results indicated a boosting effect of the 5 Gy doses on the leaf tissues as well as the seeds. The variability in the responses observed seemed to indicate some mutation, both positive and negative, at the cellular level of the tissues. However, these changes could not be detected through the DNA-fingerprints obtained through the RAPD-PCR analysis of the DNA extracted from the irradiated explants. These gave similar fragments showing that some more sophisticated analytical methods such as Southern blotting and AMD (amplification and mismatch detection) could be used for the analysis of the genomic sequence variation.

INTRODUCTION

Species within the genus Anthurium, family Araceae, are highly prized for their exotic flowers and foliage which make demand for propagating material and new cultivars high. Commercial cultivation of Anthurium in Mauritius started about 30 years ago and over the years, Anthurium has become undoubtedly one of the most economically important crops in Mauritius. In the year 2000, 95 % of the flowers exported consisted of Anthurium, showing its significance in our horticultural industry. In fact, Mauritius ranks third in its production, which is about 10.2 million stems per year, after the Netherlands with 25 million stems per year and Hawaii with some 11 million flowers per year (APEXHOM, 2001). With this production capacity, Mauritius is actually facing a severe competition on the world market since we have to keep in line with these two countries and at the same time, other countries like China seem to be emerging as potential producers. Furthermore, we are not yet specialized with the newest technologies like genetic engineering that may help in developing better varieties. In a recent report of the MoAFT&NR on the “Sustained Programme for Agricultural Diversification – A non-sugar sector strategic plan 2003-2007” much emphasis has been laid on Anthurium as being an important part of the floriculture industry in Mauritius since the 1960’s. The report also highlighted the decreasing volume of exported flowers (from 16.5 million in 1995 to nearly 13 million in 1998). This was mainly attributed to the unavailability of new varieties that were formerly procured from the Netherlands. Another key issue is the research back-up that is needed to sustain our economy by creating “typical Mauritian varieties” through appropriate breeding programmes.
Anthurium is conventionally propagated by seeds and, therefore, cultivation is hindered by problems due to the inherent heterozygosity. Although traditional techniques of vegetative propagation such as the use of stem cuttings and suckers exist, they are tedious and not practical when carried out on a large scale. Tissue culture greatly increases the normal multiplication rate of plants and can provide a source of clean material which has become increasingly important due to outbreak of bacterial and other diseases such as anthracnose, blight, leaf spot, root knot and bacterial wilt caused by \textit{Xanthomonas campestris} pv. \textit{diffenbachiae}. The “Plant Quarantine Screenhouse”, which started operating in 2002 and the lifting of the import ban on Anthurium actually provided a new enhancement in the industry by allowing safe introduction of plantlets.

The method for in vitro production of plantlets of \textit{Anthurium andreanum} was first developed by Pierik \textit{et al.} (1974). The production of in vitro plants directly from proliferating axillary buds (Kunisaki, 1980), adventitious buds (Cen \textit{et al.}, 1993), leaf or petiole organogenic callus culture (Pierik \textit{et al.}, 1974; Pierik, 1975, 1976; Finnie & Van Staden, 1986; Kuehnle & Sugii, 1991) and from somatic embryos derived from in vitro grown leaf blade explants (Kuehnle \textit{et al.}, 1992) has been reported. All workers found that there was great variation in the requirements of different genotypes. Methods for several other varieties may have been worked out by commercial establishments but these are not available for general use. Hence, we have undertaken to develop suitable methods or modify existing ones for tissue culture of three varieties of Anthurium. This will be of great help in micropropagation and for future in vitro breeding work to develop resistant varieties.

Mutagenic agents have been used to induce useful phenotypic variations in plants for more than 70 years (Foster and Twell, 1996). A large number of mutant lines have been isolated from many plants and these were used for plant research and crop breeding purposes (Evans, 1962; Auerbach, 1976; Gottschalk, 1983). New techniques are needed for further improving crop cultivars apart from the traditional plant breeding. “Mutation breeding” is therefore being promoted as a means to create additional variation. The application of ‘ionizing radiation’, ‘chemical mutagens’ as well as ‘somaclonal variation from tissue-culture’ is quite common in the creation of genetic variation. Novel plant mutants like maize, alfalfa, potato, banana, and barley among others and other cell lines of agricultural and industrial interests generated from tissue culture have also been quite popular (Collin and Dix, 1990). Physical mutants like ionizing radiations (X-rays, gamma rays and neutrons) and UV light, and also a series of chemical agents are common examples of mutagenesis techniques that have a high efficiency at generating mutations in plants, animals as well as bacteria. In addition, the outcomes of these treatments can at least be predicted to a certain extent.

The commonly used mutagenic agents cannot produce new genes but in fact they only alter those present in the treated genotype. Ionizing radiation, for instance, generates chromosomal breaks which, following DNA repair, result in a variety of chromosomal aberrations. ‘Gene mutations’ are less frequent than ‘chromosomal mutations’, which include translocations, inversions, deletions and deficiencies. Mutations in the narrow sense affect parts or sections of a gene, either single base pairs or groups of them. Exchange of base pairs or alterations of their sequence may change the primary gene product and by way of a more or less complicated chain reaction of events ultimately lead to a modified phenotypic expression of one or several traits. Sometimes the gene is affected in such a way that it cannot code for any product. The recovery of mutants induced by high levels of mutagens is limited by somatic effects, such as reduced viability, growth abnormalities and reduced fertility. Therefore, every mutagen has a most effective dose, which produces the maximum level of mutagenesis with minimal somatic effects. Apart from the choice of the proper mutagenic agent, the dosage and the treatment conditions are important. Consideration must also be given to the plant materials treated. For example:

- The stage in the life cycle of the plant or plant organs (seeds, pollen, vegetative meristems, etc)
- The sensitivity of the plant species to the effects of the mutagenic agents
- The possible genotypic differences in sensitivity to the mutagenic treatments

Isolation of plant nucleic acid (RNA or DNA) is usually required for the following:

- Genome characterization
- Mapping procedures (using genetic markers)
- Identification and isolation of plant genes for genetic engineering
Induced mutation and in vitro culture of *Anthurium andreanum*. D. Puchooa and D. Sookun.

The genomic sequence of *Anthurium andreanum* has not yet been defined. As such, molecular techniques requiring no specific sequence information, as is the case with RAPD, can be used for its DNA analysis. The rationale behind this method is that the generation of RAPD markers is based on the probability that a DNA sequence, homologous to that of a short, oligonucleotide primer (10-mers for RAPDs) will occur at different sizes on opposite strands of a DNA template that is amplifiable by PCR (Waugh and Powell, 1992).

MATERIALS AND METHODS

- **In Vitro Culture Studies**

*Anthurium andraeanum* plants grown in the University farm shadehouse were used for the experiments.

Young unfolded leaves were collected and briefly washed under running tap water. Pre-sterilization was done on the whole leaf by soaking in a solution of 0.6% Benlate (benomyl) for 30 minutes. Sterilization consisted of washing the leaves with diluted liquid soap and thorough rinsing with tap water followed by a dip in 70% alcohol for 30 seconds and soaking in 1.5% sodium hypochlorite, containing 2 drops of Tween 20. After 20 minutes of gentle agitation, the leaves were rinsed three times in sterile distilled water with 15 minutes in each rinse and a final rinse for 30 minutes. The leaves were then cut into explants of 1 to 2 cm² and inoculated abaxially onto callus induction medium.

The following culture media were used:

<table>
<thead>
<tr>
<th>Additive</th>
<th>Callus initiation</th>
<th>Shoot development</th>
<th>Rooting</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>1.0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>2,4-D</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>IBA</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

- **Experiment with mature embryos**

This was more or less the same as for the callus initiation medium except for:

A higher level of ammonium nitrate, i.e. 720 mg L⁻¹ instead of 200 mg L⁻¹.
20 mg L⁻¹ glucose instead of 30 mg L⁻¹ of sucrose.
PGRs NAA (0.1 mg L⁻¹) for rooting; BA (0.2 mg L⁻¹) for shooting and 0.1mg L⁻¹ of GA.
Initial incubation at 100 lux or in dark and transfer to 16 h L/ 8 h D (2 400 lux) after a few weeks.
1.2 g L⁻¹ of activated charcoal in the media.

In the pre-sterilisation step, the seeds were thoroughly rinsed under running tap water for at least 30 minutes. They were dipped in 200 mL of 3.25 % commercial bleach. This was decanted and the seeds were again rinsed under running water. For the sterilisation of the seeds, 50 mL of 6 g L⁻¹ benlate and
0.4 g L\(^{-1}\) of MIC (concentrated bleach), with 2 drops of Tween 20 / 100mL, were used with constant stirring for 3 hours. The seeds were washed in sterile distilled water for 30-60 minutes to remove all traces of the fungicide and the bleach. Under the laminar flow cabinet, the seed coat was removed with a scalpel and a forceps. The seeds were then washed briefly in some sterile water just prior to inoculation in the medium.

- **Irradiation Studies**

In this study, the explants consisted of calli, embryos and tissue-cultured plantlets of *Anthurium*. The variety ‘Nitta’ was used throughout the experiment. The irradiation was carried out at the ‘Entomology Department’ of the Agricultural Research and Extension Unit (AREU) at Reduit. The apparatus used for irradiation is kept in a highly protected area with restricted access as strong radiation may be emitted. It consisted of a “radiation cell” and the dose rate had to be calculated. The cell was rotated to enable the dose rates to be uniform throughout.

The gamma rays doses that were required in the experiments (5, 10 and 15 Grays) had to be regulated according to the time of exposure of the plantlets to the ionising radiation emitted from \(^{137}\)Cs (Caesium) radioactive compound. The equivalent time lapse is obtained through a series of calculations and it should be noted that the irradiation fluctuates with time due to the changing half-life of the compound and with the capacity of the apparatus.

- **DNA-extraction**

The CTAB method for DNA extraction was used for isolating DNA from the leaves of *Anthurium*, variety ‘Nitta’. For this preliminary experiment, the plant materials were obtained from the University Farm. The procedure used was an adaptation of the CTAB method described by Murray and Thompson (1980), Dellaporta *et al.* (1983), Saghai-Marooof *et al.* (1984) and Rogers and Bendich (1988). A few modifications had been carried out such as the inclusion of PVP in the CTAB extraction solution to remove polyphenolic contaminants (Couch and Fritz, 1990). Another method of DNA extraction, where “Sarcosyl” replaced the CTAB in its mode of action was attempted. PVP (m.wts 10000 and 40000) were used in different sets of experiments to see if there were any effects on the DNA quality.

- **RAPD**

The methods used had been adapted from an M.Phil research project (Buldewo, S 2002; Pers. Comm.). The primers (10-mers Primers) used in the different PCR reactions are OPA 10, OPA 18, OPW 02, OPW 04 and OPD 01.

**RESULTS**

- **Tissue Culture Studies**

Contamination was a major problem encountered during this study. The pre-sterilization and sterilization methods devised, reduced the contamination level considerably (<10%), independent of variety. However, the concentration of Benlate used during pre-sterilization and the number and duration of rinses in sterile distilled water following sterilization was crucial. Benlate at concentrations higher than 0.6% caused the leaves to become chlorotic while residual sodium hypochlorite caused the explants to become necrotic.

Various concentrations of cytokinin (BA) and auxin (2,4 - D) added to either modified Murashige and Skoog (1962) medium or modified Nitsch (1969) medium were tested in a preliminary experiment. Of the two media tested, Nitsch (1969) with reduced ammonium nitrate concentration (200 mg L\(^{-1}\)) proved to be the best for callus induction (Table 2). For regeneration, best results were again obtained with Nitsch medium but with the ammonium nitrate concentration increased to 720 mg L\(^{-1}\). The same response was noted for all varieties under investigation.
Table 2 Influence of ammonium nitrate concentration on shoot development from callus, obtained from leaf explants grown on modified Nitsch medium, of different varieties of *A. andraeanum* cultured under low light intensity and supplemented with 0.5 mg L\(^{-1}\) BA.

<table>
<thead>
<tr>
<th>Variety</th>
<th>NH(_4)NO(_3) conc (mg L(^{-1}))</th>
<th>Number of callus (&gt; 5 mm)</th>
<th>% callus forming shoots</th>
<th>No of shoots per callus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitta</td>
<td>200 *</td>
<td>24</td>
<td>16.7</td>
<td>1 - 5</td>
</tr>
<tr>
<td></td>
<td>720 **</td>
<td>24</td>
<td>100.0</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td>825 ***</td>
<td>24</td>
<td>8.3</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Osaki</td>
<td>200 *</td>
<td>24</td>
<td>20.8</td>
<td>1 - 5</td>
</tr>
<tr>
<td></td>
<td>720 **</td>
<td>24</td>
<td>91.7</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td>825 ***</td>
<td>24</td>
<td>8.3</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Anouchka</td>
<td>200 *</td>
<td>24</td>
<td>12.5</td>
<td>1 - 5</td>
</tr>
<tr>
<td></td>
<td>720 **</td>
<td>24</td>
<td>87.5</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td>825 ***</td>
<td>24</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*modified Nitsch medium, **original Nitsch medium, *** modified MS medium.

BA (1 mg L\(^{-1}\)) and 2,4-D (0.1 mg L\(^{-1}\)) induced callus in all three varieties. Callussing also occurred at lower and higher concentrations but at much lower frequencies. Callus induction began after two weeks in culture and was produced along cut edges of the leaf explants (Figure 1, Plate 1). Incubation in continuous darkness was found to enhance callussing. The calli were firm and pale yellow in colour. Callus formation was more prominent when veins, major or minor, were present on the explants. This can be explained by the presence of metabolically active phloem tissues which are capable of growth in culture as well as retaining some of their endogenous growth factors for additional stimulation of explant growth (Finnie and Van Staden, 1986). Division and subculture of the callus was done every 12 weeks.

Figure 1 Mean fresh weight and dry weight of callus of the three varieties.
Induced mutation and in vitro culture of Anthurium andreanum. D. Pachooa and D. Sookun.

Transferring callus from the callus induction medium to Nitsch basal medium (720 mg L⁻¹ NH₄NO₃) supplemented with BA (0.5 mg L⁻¹) and culturing for 16h per day to an illumination of 5.0 W m⁻², caused shoot formation and a depression in callus growth. The shoots were both adventitious and axillary in nature.

Allowing the regenerated shoots to stand for over two months on Nitsch (1969) basal medium supplemented with BA (0.5 mg L⁻¹) caused spontaneous rooting to occur. However, transferring the shoots to Nitsch (1969) basal medium supplemented with IBA (1.0 mg L⁻¹), improved rooting and this was further enhanced when activated charcoal (0.04%) was added to this medium. The level of ammonium nitrate used (720 mg L⁻¹) was essential for rooting as a reduced level (200 mg L⁻¹) delayed rooting.

Illumination was also found to be an important factor in the rooting of shoots as callus of all three varieties, grown in the dark on the above medium, did not produce any shoots. As observed by Geier (1986) while working with leaf explants of Anthurium scherzerianum, the time of rooting was related to the extent of shoots and leaflet development; the larger shoots with more prominent leaflets forming roots quicker.

Plantlets with well-developed roots were hardened by transplanting in vermiculite and growing in a mist house with very low light intensity and high humidity. No losses were observed and the plantlets were transferred to the shadehouse after two months. However, considerable losses were observed in plantlets without roots or poorly developed roots when transferred to vermiculite.

- **Irradiation Studies**

The different explants that have been subjected to the three doses of irradiation (5, 10 and 10 Gy) have shown amazing results in terms of the phenotype as compared to the control experiments, where there was no irradiation. The parameter to determine dose-dependent irradiation damage was the survival of the explants after irradiation. Some of the responses observed during culture are shown below.

After optimising the conditions for the in vitro culture of the embryos, these were irradiated at the three doses. The response of the seeds to irradiation was expressed as from the 4th week of culture. There is a variation in the different responses of the seeds to each dose (Figure 2). As compared to the control experiments, the “5 Gy” doses allowed the seeds to have a higher survival rate as compared to the “10 Gy” and “15 Gy”. Apart from the higher survival rate of the “5 Gy” treatment, these seeds also showed better growth responses in the “Nitsch” medium. They grew faster and more vigorously, producing shoots within six weeks of culture.

For the callus culture, at the 4th week of culture, the number of calli from the 5 Gy treatments were highest in number as compared to the 10 Gy, 15 Gy and even the “control”. By week 8, the number of explants at 15 Gy was completely eliminated, as these were no longer viable (Figure 3).

- **Phenotypic Observations**

The response of the leaves to callus induction was quite low as it took about 4-8 weeks to get the callus. Some plantlets that were inoculated in callus-induction medium also formed good callus that regenerated more shoots. The observations made on the somatic embryos that were irradiated also supported the other points noted in the calli and plantlets.

Different responses observed after irradiation (Plates 2-9). It was noted that the explants with the ‘5 Gy’ treatment gave very good responses (even better that the control experiments), as shown by the green calli and shoots (and the larger number of shoots). However, the ‘10 Gy’ radiation showed some
necrotic effects since part of the explants turned brown (though not the whole explants). The ‘15 Gy’ doses were the most lethal to the *Anthurium* tissues. In fact, the callus did not develop well as most of the leaf pieces died within two weeks’ culture. Those that survived after this period produced brown plantlets eventually.

**Figure 2** Number of seeds surviving after irradiation

![Graph showing number of seeds surviving after irradiation](image)

**Figure 3** Survival rate of calli

![Graph showing survival rate of calli](image)
Induced mutation and in vitro culture of Anthurium andreanum. D. Pachoooa and D. Soo kun.

The phenotypic results seem to indicate the boosting effect of the 5 Grays doses on the leaf tissues. These enhanced the quality of the in vitro plantlets, which could possibly have an effect on the Anthurium plants under in vivo conditions (that is, after acclimatization). The variability in the responses indicates that the radiation doses may have caused mutation.

- **DNA extraction**

The CTAB extraction was performed but the DNA obtained did not perform well with the PCR reactions since there was presence of contaminants that inhibited the reactions. Also, the method was too time-consuming and tedious. Subsequently, the alternative method of DNA-extraction was used and was found to be better. The DNA obtained was of a better quality (though in lesser amount) in terms of the ‘spectrophotometric’ analysis and the RAPD-PCR reactions. It also had the advantage of being a shorter process.

- **RAPD analysis**

In preliminary experiments, a series of PCR reactions were carried out to determine the optimum DNA template concentration and primers to be used for the analysis. The PCR was then carried out with the DNA from irradiated callus tissues and from the mother plant (all variety ‘Nitta’) at optimized conditions. An example of a DNA-profile obtained is given in Figure 4. The basepair sequences for the DNA extracted from calli irradiated at the three doses gave similar banding patterns. From these results, it showed that the RAPD was inefficient in detecting the more precise genomic alterations that have occurred due to the gamma rays.
- RAPD-Profile: Using Primer OPB 20 at 10 ng

After DNA extraction from the irradiated calli and from Anthurium (Nitta) leaves under the same conditions, the above results were obtained. All four calli DNA gave similar patterns, and these corresponded to that from the mother plant. Hence, at this level no difference in the banding patterns was observed.

Figure 4 Lane 1: Marker VI, Lane 2: DNA from leaf explants, Lane 3: DNA 5 Gy (irradiated), Lane 4: DNA 10 Gy (irradiated), Lane 5: DNA 15 Gy (irradiated), Lane 6: DNA 0 Gy (not irradiated) / control, Lane 7: Negative control

**DISCUSSION**

Hormonal regulation of auxin and cytokinin balance has long been recognized as a key factor in the control of cell division and organogenesis in tissue culture (Murashige, 1977). Our research demonstrated that exogenously applied BA (1.0 mg L\(^{-1}\)) and 2,4-D (0.1 mg L\(^{-1}\)) was essential for callus induction from leaf explants of all the three varieties of Anthuriums. Shoot regeneration from the callus occurred when BA (0.5 mg L\(^{-1}\)) alone was used while rooting required removal of the BA from the medium and addition of IBA (1 mg L\(^{-1}\)). The difference in regeneration capacity and mode of regeneration at concentrations higher and lower than optimum may be explained on the basis of variation in the endogenous levels of these growth hormones in leaf tissues.

From the experiments on seed culture for example, the 5 Gy treatment showed a higher survival rate (70% at week 8) as compared to the other treatments (Figure 3). The results were even better than those obtained from the “control” experiments, both in terms of survival rate (60%) and in the morphological variation of the seeds in culture (Plate 9). The calli and plantlets also expressed better responses at the 5 Gy but lethality at the 15 Gy doses, whereas the 10 Gy treated explants were moderately lethal to the radiation. These observations demonstrated the probable mutations that have taken place in the Anthurium tissues due to the gamma radiation. Apart from the dose effects, the responses were controlled by a number of parameters, including the genotype, the type of explant, the orientation of the explant on the culture medium, and the origin of the explant from the mother plant (Douglas, 1985). In fact, the better responses observed for the “5 Gy” treatment could suggest that the type of chromosomal alterations that took place eventually produced a change in the morphology. This was expressed under in vitro conditions. The higher gamma-ray doses may have produced other modifications that caused the tissues and calli to become necrosed. However, from the RAPD-profiles, these genomic changes could not be detected.
CONCLUSION / RECOMMENDATION

Mauritian Anthurium, being in high demand in the world market, forms an important part in our agricultural sector and in our economy. However, with the fierce competition faced by other Anthurium-producing countries, we have to diversify our production. This could be achieved by the creation of new varieties. Though breeding and vegetative propagation is an option, it is however a very time-consuming process and produces a few blooms per year. Hence, “irradiation mutagenesis” and “tissue-culture” provide another interesting alternative. This project is a preliminary attempt in determining the possibility of using the gamma-ray irradiation to induce mutations of agricultural importance in our Anthurium varieties.

The tissue-culture studies carried out on the three varieties, namely, Nitta, Ozaki and Anouchka, showed that the protocol adopted is efficient and can be used for other local varieties for micropropagation. The irradiation carried out through the gamma-rays ($^{137}$Cs) showed that the 5 Gy doses were optimum in producing promising morphological characteristics that could be of significance for creating desirable traits. However, for the genetic analysis of these induced mutations, some other methods than RAPD, which may be more sophisticated and demanding, may be more useful in determining the precise types of mutagenesis at the genomic level. With Anthurium, which relies on caulogenesis for regeneration, this is more challenging, as the mutation could also be a result of somaclonal variation. The phenotypic effects of any mutations will only be apparent after the tissue-cultured plantlets are hardened and grown until the flowering stage.

REFERENCES


Induced mutation and *in vitro* culture of *Anthurium andreanum*. D. Puchooa and D. Sookun.


THE ROLE OF DIAZOTROPHIC BACTERIA IN THE NITROGEN NUTRITION OF SUGAR CANE IN MAURITIUS: PRELIMINARY RESULTS

JFY Moutia, G Umrit, AS Saumtally and KF Ng Kee Kwong
Mauritius Sugar Industry Research Institute

ABSTRACT

Research has been initiated at MS IRI to investigate means of reducing the dependence of the sugar industry on inorganic fertilizers especially nitrogen. In that context, the contribution of biological nitrogen fixation is being examined. Attempts have been made to isolate bacterial species involved in this process. Preliminary findings are presented on the isolation, distribution and characterisation of two important diazotrophic bacteria namely Herbaspirillum and Gluconacetobacter spp known to be involved in N-fixation in several sugar cane producing countries. Herbaspirillum spp have been found to be widely distributed and more frequently encountered compared to Gluconacetobacter spp which were restricted to abandoned fields. The potential of the isolates collected, to fix nitrogen, has been gauged by the acetylene reduction assay (ARA) and results showing they have the ability to fix nitrogen are encouraging.

Keywords: Herbaspirillum, Gluconacetobacter diazotrophicus, acetylene reduction assay, biological nitrogen fixation

INTRODUCTION

Sugar cane production in Mauritius relies on the intensive use of inorganic fertilisers which account for approximately 10% of the total production cost. Of these, nitrogen (N) fertilisers are of key importance both from the economic and environmental viewpoint. The use of N fertiliser in sugar cane cultivation in Mauritius has risen from 2500 t in the late 1940s to 11 000 t (representing MUR 200 million) at present (Ng Kee Kwong et al. 1999) for an annual sugar production of 625 000 t. The efficiency of N utilisation is, however, low, rarely exceeding 40% (Ng Kee Kwong and Deville 1987). While the current N fertiliser application rate (on average 140 kg N ha⁻¹ yr⁻¹) is similar to that of many other cane-producing countries, yet it is much higher than that of Brazil for example (on average 60 kg N ha⁻¹ yr⁻¹ for a mean cane yield of 65 t ha⁻¹ yr⁻¹). Since the impact of N fertiliser use on surface and ground water quality (Ng Kee Kwong 2001) and on the atmosphere (Ng Kee Kwong et al. 1999) is small and within tolerable limits, its potential effect cannot be ignored and should be eliminated altogether. There is consequently a need to seek alternative technologies that will reduce the reliance of the Mauritian sugar industry on inorganic N fertilisers, thereby not only reducing the cost of production, but also minimising any impact of N fertilisers on freshwater quality.

The contribution of biological nitrogen fixation (BNF) to sugar cane was first demonstrated by Ruschel et al. (1975) using ¹⁵N-enriched N₂ gas. Later, ¹⁵N isotope dilution and N balance studies (Urquiaga et al. 1992, Boddey et al. 1995) showed that several Brazilian varieties of sugar cane were capable of obtaining over 60% of their N requirement (equivalent to > 150 kg N ha⁻¹ yr⁻¹) from BNF. In fact, as reported by Boddey (1995), BNF associated with sugar cane plays a key role in making the Brazilian bioethanol program viable. More recently, Biggs et al. (2000) reported BNF contributions ranging from 0 to 45% of the crop’s N requirement for Australian sugar cane.

Micro-organisms capable of fixing N₂ are called diazotrophs. Amongst the diazotrophic bacteria associated with sugar cane are Azospirillum spp, Herbaspirillum seropedicae, H. rubrisubalbicans and Gluconacetobacter diazotrophicus. They are found within the plant tissues (endophytic) namely roots, stems and leaves (Purchase 1980, Baldani et al. 1986, Cavalcante and Dobereiner 1988, Gillis et al. 1989; Boddey et al. 1991). Neither G. diazotrophicus nor Herbaspirillum spp are found in the soil and hence are obligate endophytes (Baldani et al. 1997).
**Herbaspirillum** spp were first isolated from the roots of maize and other cereals (Baldani et al. 1986). Most of the isolates of *Pseudomonas rubrisubalbicans* (causal agent of mottled stripe of sugar cane) were found to be able to fix nitrogen and were identical in most respects to *Herbaspirillum* (Pimentel et al. 1991). *P. rubrisubalbicans* was subsequently reclassified and renamed *Herbaspirillum rubrisubalbicans*. *H. seropedicae* has been isolated from a wide range of graminaceous crops, including sugar cane, rice, sorghum, and many pasture grasses (Baldani et al. 1986) whereas *H. rubrisubalbicans* seems to be restricted to sugar cane where it occurs in high numbers without causing symptoms of the disease except in a few varieties sensitive to mottled stripe disease (Olivares et al. 1997).

Although a range of N₂-fixing bacteria including *Azotobacter*, *Azospirillum* and *Enterobacter* have previously been isolated from the roots, stems and leaves of sugar cane (Boddey et al. 1995), none of these bacteria were found to occur in sufficiently large numbers to account for the high rates of N fixation reported. The discovery of the endophytic diazotroph *Gluconacetobacter diazotrophicus* (Cavalcante and Dobereiner 1988) in roots, stems and leaves of sugar cane has opened a new avenue of research in BNF in sugar cane. *G. diazotrophicus* is regarded as the most likely contributor to BNF in sugar cane and a large body of knowledge has been accumulated on the genetics and physiology of this bacterium (Sevilla and Kennedy 2000). *G. diazotrophicus* occurs in large numbers in the roots, basal and apical stems, leaves and trash of sugar cane in several regions of Brazil as well as Mexico, Cuba, and Australia (Cavalcante and Dobereiner 1988, Gillis et al. 1989, Li and MacRae 1992) with populations ranging from $10^3$ to $10^7$ CFU g⁻¹ f.w. It was also isolated from a few samples of washed roots and aerial parts of *Pennisetum purpureum* cv. Cameroon and from sweet potatoes (*Ipomea batatas*) (Dobereiner et al. 1988).

In Mauritius there is a complete lack of information regarding the occurrence and diversity of endophytic diazotrophs associated with sugar cane and whether BNF is a significant contributor to the N nutrition of this crop. The objectives of this study were to attempt isolation of two endophytic diazotrophs namely *Herbaspirillum* spp and *Gluconacetobacter* spp from various plant parts, characterise the isolates collected and to detect variability if it existed and verify if the isolates were capable of fixing N₂ *in vitro*

**MATERIALS AND METHODS**

**Sampling**

*Herbaspirillum* spp

Leaf and root samples from both symptomatic and asymptomatic plants were collected from different varieties (M 1658/78, M 292/70, M 3391/95, M 3512/95 and M 1176/77) and locations (Réduit, Bagatelle, Cluny, Union Park, Henrietta, Gentilly, Beau Champ, FUEL, Ferney, Bel Etang, Midlands, Belle Rive).

*Gluconacetobacter* spp

One hundred and ten samples were collected from abandoned fields of all major agroclimatic zones of Mauritius. Nine varieties (R 570, M 376/64, M 3035/66, M 13/56, S 17, M 1176/77, M 695/69, M 1557/70 and M 555/60) were sampled for leaves, leaf sheaths, stems, roots and trash of sugar cane.
Isolation

*Herbaspirillum* spp

*Leaf and root*

Leaves (showing the characteristic stripes associated with mottled stripe disease) or roots, were washed with soap under tap water. They were then cut in 10 cm long pieces and soaked for 15 min in 1% Chloramine-T in sterile distilled water (SDW) in 500 mL flasks. The flasks were shaken occasionally. The plant pieces were then rinsed by transferring them to clean sterile flasks and soaking them in three changes of SDW for 10 minutes each. The leaf strips were further cut into smaller pieces of about 1 x 0.5 cm² whereas roots were processed directly and placed in special “Universal” extraction bags. To one gram of leaf/root material, 9 mL of saline extraction solution was added. The bags were loaded in a HOMEX 6 homogeniser (BIOREBA AG, Switzerland) and crushed for 1 min. The sap extract was serially diluted to give dilutions of 10⁻², 10⁻³, 10⁻⁴ and 10⁻⁵ by taking 1 mL of extract and adding 9 mL of saline solution to it. 100 µL of the diluted extracts were used to inoculate vials containing 5 mL of either NFb or JNFb semi-solid medium.

*Gluconacetobacter* spp

*Leaf, leaf sheath and root*

Sap extraction from leaves, leaf sheaths and roots was similar to the corresponding methods adopted for *Herbaspirillum* except that no symptom was apparent.

*Stalk*

Stalks were washed with soap under tap water. Stalk pieces (internode or node) of 4-8 cm long were cut from samples. The stalk pieces were soaked in 1% Chloramine-T for 5 min with occasional shaking. The stalk pieces were then transferred to clean sterile flasks and rinsed with three changes of SDW for 10 min each. The rind of the stalk pieces was then removed with a disinfected knife following which the sugar cane tissue was cut into small pieces. One gram of the latter material was processed and diluted as described above for *Herbaspirillum* leaf/root extraction and 100 µL inoculated in vials containing 5 mL of LGI-P semi-solid medium.

*Trash*

Trash was collected from around cane stools and cut into strips of about 10 cm long. The strips were placed in flasks containing saline solution and shaken at 100 rpm for 1 h on an orbital shaker. The solution which was brownish in colour was serially diluted (ten-fold) as explained above and 100 µL were used to inoculate vials containing 5 mL of LGI-P semi-solid medium.

Purification, sub-culturing and plating on solid media

Vials showing growth of bacteria characteristic of those sought were purified by transferring a loopful of bacteria into new vials containing the same medium followed by incubation at 30-32°C. This step was repeated until a clean (uncontaminated) growth was apparent. The latter was then streaked on the corresponding solid medium in an attempt to recognise typical colonies characteristic of the bacteria sought. The identified colony was then re-inoculated into the initial semi-solid medium to ensure growth on N-free medium and in parallel streaked on solid agar of the same medium. Cultures were observed for the characteristic colony morphology, size and colour.
Media preparation

NFb, JNFb and LGI-P media

NFb and JNFb media were prepared according to published recipes (Kirchhof et al. 1997). LGI-P medium was prepared according to Kirchhof et al. (1998).

Potato-P medium

The composition of potato-P medium per litre was: potato (200 g); raw sugar (100 g); micronutrient solution (2 mL) and vitamin solution (1 mL) as for NFb; technical agar (25 g).

The potato was peeled and washed. It was cut into small cubes and boiled in 400 mL distilled water (DW) for 30 min. The preparation was filtered through cotton wool. The filtrate was kept and the remaining components were added. The volume was completed to 1000 mL with DW and the pH adjusted to 5.5 with acetic acid.

Dygs liquid medium

The composition of Dygs liquid medium per litre was: K₂HPO₄ (0.5 g); MgSO₄.7H₂O (0.5 g); glucose (2 g); bacteriological peptone (1.5 g); yeast extract (2 g) and glutamic acid (1.5 g); malic acid (2 g) was required for Herbaspirillum spp but not for Gluconacetobacter spp. The pH was adjusted to 6.0.

Saline solution for dilution

The saline solution per litre consisted of the following: KH₂PO₄ (3.4 g); MgSO₄.7H₂O (0.2 g); NaCl (0.1 g); CaCl₂.2H₂O (0.02 g); micronutrient solution (2 mL) (as for NFb above), 1.64% FeEDTA solution (4 mL) and KOH (4.5 g). The volume was completed to 1000 mL with DW and the pH adjusted to 7.0 with KOH.

Motility test

Motility GI medium (DIFCO, USA) was prepared according to the manufacturer’s instructions and used to verify if the presumptive isolates of Herbaspirillum and Gluconacetobacter were motile. Incubation was done in the dark at 35°C.

Gram stain

A 3-step kit from Becton Dickinson Microbiology Systems (Maryland, USA) was used for the Gram stain test. Colonies from an 18-24 h potato dextrose agar (PDA) culture were emulsified in saline solution (0.85% (w/v) NaCl). The latter was then used to prepare a thin, uniform smear on a clean glass slide. The smear was air dried and heat-fixed by passing the slide two to three times through a low flame. The slide was cooled to RT before staining. The fixed smear was flooded with the primary stain (Gram crystal violet) and stained for 1 min. The primary stain was removed by washing gently with cold tap water. The slide was then flooded with the mordant (Stabilised Gram Iodine) for 1 min. The slide was then decolourised by running 3-step Gram Safranin-S on it. More decoloriser was added and retained on the slide for 20-50 s. The decoloriser was removed by gently washing the slide with cold tap water. The slide was air dried.

Light microscopy

The Gram stain smear was examined under an oil immersion lens at a magnification of X 1000. The staining result and shape of the bacteria were noted and the size measured using an ocular micrometer.
Oxidase test

Oxidase identification sticks (Oxoid BR64A, UK) were used for this test on 18-24 h old PDA cultures. The already prepared stick was left at RT for 5 min following which the impregnated end was touched on a well separated representative colony of the test organism. The stick was rotated to pick up a small mass of cells. The stick was examined after 3 min for a colour change.

Catalase test

A drop of hydrogen peroxide (30% w/v) was added to a small mass of cells on a clean glass slide. The slide was examined for bubble formation.

Acetylene reduction assay (ARA)

Nitrogen fixation activity (nitrogenase activity) of isolates was assessed by the Acetylene Reduction Assay (ARA). Isolates were grown for 24 h in Dygs liquid medium at pH 6.0. The bacteria were harvested by centrifugation at 10000 x g for 5 minutes in a Beckman Avanti benchtop centrifuge and pellets were rinsed by re-suspension in SDW followed by another centrifugation under the same conditions. The clean pellet was re-suspended in 10 mL SDW. The optical density of this inoculum was adjusted with a Beckman DU 65 spectrophotometer to give a transmittance of $54 \pm 2\%$ at a wavelength of 650 nm. Then 100 $\mu$L of the bacterial suspension were aseptically inoculated into 8 mL glass vials containing 5 mL of semi-solid medium of either NFb (for *Herbaspirillum* spp) or LGI-P (for *Gluconacetobacter* spp). The vials were capped with sterile cotton wool and incubated at 30-32°C for 3-5 d. After the incubation period, the cotton wool was removed and replaced by a “Subaseal” stopper leaving a 3 mL headspace. Using a 1 mL gas-tight syringe, 0.3 mL of air was removed and the same volume of acetylene was injected giving a final concentration of 10% acetylene in the vials. The latter were incubated at RT for 5 h followed by analysis of the ethylene concentration in the headspace with a Varian 3400 CX Series gas chromatograph using an external standard calibration and the following conditions:

- **Detector**: Flame ionization detector (FID); temperature, 200°C; hydrogen, 25 mL min$^{-1}$; air, 200 mL min$^{-1}$.
- **Column**: Stainless steel, 2m x 2 mm ID; Porapak N (80-100 mesh).
- **Carrier gas**: Nitrogen, 45 mL min$^{-1}$.
- **Oven temperature**: 65°C
- **Retention times**: Ethylene, 1.6 min; Acetylene, 2.6 min.

RESULTS

Isolation

*Herbaspirillum* spp

Eighteen isolates of presumptive *Herbaspirillum* spp were collected from varieties M 1658/78 (Réduit, Union Park, Belle Rive, Beau Champ, Bagatelle, Ebene, Gentilly, Cluny, Bel Etang, Midlands), M 292/70 (Henrietta), M 3391/95 and M 3512/95 (FUEL) and M 1176/77 (Réduit). M 1658/78 was by far the variety most frequently infected and its susceptibility to mottled stripe disease is well-known. As far as sampling site was concerned, the humid and superhumid zones, which are favourable to disease development, showed the highest prevalence of *Herbaspirillum* sp. Both leaf and root samples gave rise to presumptive *Herbaspirillum* sp. at sap dilutions of $10^2$ for roots and $10^3$ to $10^4$ dilutions for leaf extract.

Growth of presumptive *Herbaspirillum* sp. in semi-solid NFb medium was characterised by a thin white pellicle or film initially in the centre of the vial. This pellicle migrated towards the surface of the medium within a few days. After 7 d, the pellicle was white and thick at the surface. The medium which was initially pale-blue changed to a more intense blue colour with time. In JNFb semi-solid medium, the presumptive *Herbaspirillum* sp. grew as a thin white pellicle in the centre of the vial. The
pellicle migrated upwards to the surface and a white haze could be seen below it. After 7 d the white pellicle thickened and the medium changed from pale green to pale blue with time.

A loopful of bacteria from the vial was streaked onto NFb and JNFb solid media. On NFb, separate milky-white colonies of approximately 1 mm diameter were observed. A dense centre was evident after 2-3 d and it became green after 10 d. The colour of the medium changed from pale green to pale blue. On JNFb medium, slimy, milky-white colonies of 0.5-1.0 mm in diameter with a dense centre were apparent after 3 d. The colonies reached 2-3 mm in diameter after 6 d and the dense centre became pale-green in colour. The colour of the medium changed from pale-green to pale-blue with increased growth.

**Gluconacetobacter spp**

Seven presumptive isolates of *Gluconacetobacter* sp. were collected from four different varieties (M 376/64, R 570, M 13/56 and M 555/60) located in all three agro-climatic zones of Mauritius. The plant parts that led to positive isolation were roots, nodal and inter-nodal tissue, leaf sheath and trash.

Growth of the presumptive *Gluconacetobacter* sp. on semi-solid LGI-P medium was characterised initially by a thin yellow pellicle in the centre of the vial. The pellicle then migrated towards the surface and thickened after 3-4 d. After 7 d a thick yellow pellicle was noted. The colour of the medium below the pellicle changed from yellow to pale-yellow and eventually to colourless after 10 d.

The following was observed when a loopful of bacteria from the pellicle was streaked onto solid LGI-P, PDA and Potato-P media; on LGI-P medium, minute, shiny, transparent colonies were seen after 1-2 d. These colonies became yellow in the centre and surrounded by a transparent slime after two more days. Finally they developed an intense orange colour in the centre but still surrounded by a transparent slime after 10 d. Colonies were confluent and about 1-3 mm in diameter. On PDA medium, colonies were initially white, 1-2 mm in diameter but after 5-7 d they enlarged to reach 2-4 mm in diameter and developed a pale-brown pigmentation in the centre. The pale-brown pigmentation eventually darkened after 10 d. On Potato-P medium, the same observation was noted except that the dark-brown pigmentation was evident earlier, 5 d after streaking.

**Characteristics of presumptive isolates of *Herbaspirillum* spp and *Gluconacetobacter* spp**

The physical and biochemical characteristics of presumptive isolates of *Herbaspirillum* spp and *Gluconacetobacter* spp are summarised in [Table 1](#).

**Table 1** Physical and biochemical characteristics of presumptive *Herbaspirillum* and *Gluconacetobacter* isolates

<table>
<thead>
<tr>
<th>Genus</th>
<th>Motility test</th>
<th>Catalase test</th>
<th>Gram staining reaction</th>
<th>Size and shape</th>
<th>Oxidase test</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Herbaspirillum</em></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>Small rods 0.6-0.7 x 3-5 µm, slightly curved</td>
<td>+</td>
</tr>
<tr>
<td><em>Gluconacetobacter</em></td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>Small straight rods 0.9 x 1.5-3 µm, single or pairs</td>
<td>_</td>
</tr>
</tbody>
</table>
Acetylene reduction assay (ARA)

Figure 1 Acetylene reduction assay performed on presumptive isolates of (a) Herbaspirillum and (b) Gluconacetobacter

Figure 1 shows the results of the ARA test for both Herbaspirillum and Gluconacetobacter isolates. The amount of nitrogen fixed is directly related to the amount of nmoles of ethylene produced. The
isolates have been sorted in ascending order based on the amount of nmoles of ethylene produced per
vial per h. The ability of the *Herbaspirillum* isolates to fix N varied from 2.08 (Cluny isolate) to 13.84
(Réduit isolate) nmoles ethylene/vial/h. For *Gluconacetobacter* spp, the range was even bigger,
varying from 35.68 (Queen Victoria isolate) to 147.14 nmoles of ethylene/vial/h (Sodnac isolate).

**DISCUSSION**

Attempts to isolate *Herbaspirillum* spp from sugar cane were successful. Leaves, especially
symptomatic ones, were most often used and revealed to be an appropriate starting material for
isolation, however, one root sample from the symptomless variety M 1176/77 also led to a positive
isolation. *Herbaspirillum rubrisubalbicans* is known to be present in large numbers in leaves
(Olivares et al. 1997) especially in the protoxylem and metaxylem vessels whereas *H. seropedicae* is
known to be more prevalent in the roots and stems of sugar cane. The most susceptible variety was M
1658/78 where the bacterium was isolated most frequently from fields located in the humid and
superhumid agroclimatic zones. The presence of a pellicle 1-2 d after inoculation of semi-solid NFb
and JNFb media with plant extracts indicated successful isolation. Purification on semi-solid media
followed by streaking on solid media revealed the colony morphology of the bacterium. Small moist
colonies with green centres after five days on JNFb solid medium confirmed the presence of
*Herbaspirillum* spp to some extent (Olivares et al. 1997). Light microscopy analysis revealed the
presence of small curved rods of 0.6-0.7 x 3-5 µm that were gram-negative, catalase-negative, oxidase-
positive and motile with swarming on soft agar at 35°C. These characteristics are in line with
published descriptions of the genus *Herbaspirillum* (Holt et al. 2000a).

Attempts to isolate *Gluconacetobacter* spp did not initially meet with the same success as for
*Herbaspirillum*. Preliminary surveys in 2001 (data not shown) showed that attempts to isolate
*Gluconacetobacter* sp. from commercial fields and germplasm collections were not conclusive. It was
therefore decided to attempt isolation from fields which have been deprived of nitrogen fertilisation for
some time. Such a condition could only be found in abandoned fields which still had a few scattered
cane stools. The assumption that *Gluconacetobacter* sp. could be found more easily in fields which
had been deprived of N fertilisation for some years proved correct. This is in line with the observation
by other workers (Fuentes-Ramirez et al. 1993, Dos Reis Junior et al. 2000) that high doses of N-
fertiliser affect the population and frequency of isolation of *Gluconacetobacter* spp. Indeed,
abandoned fields with only a few scattered cane stools were the right place to search for the bacterium.

The bacterium has been isolated from nodal and inter-nodal tissues, root, leaf sheath and trash. Out of
the seven isolates collected, one was obtained from both stalk and root tissues, four from trash and two
others from leaf sheath. Light microscopy analysis revealed the presence of small, straight, rod-shaped
cells of 0.9- x 1.5-3 µm that were gram-negative, catalase-positive, oxidase-negative and non-motile
on soft agar at 35°C. These characteristics are in line with published descriptions of the genus *Gluconacetobacter* (previously *Acetobacter*) (Holt et al. 2000b).

Although 110 samples were screened for *Gluconacetobacter*, only seven isolates have been collected.
This is evidence that the fertilisation regime practised in Mauritius over the years has had a profound
negative impact on the population and distribution of *Gluconacetobacter* spp. Since four out of seven
isolates have been collected from trash, it appears that this niche favours the proliferation of
*Gluconacetobacter* sp., at the expense of other genera of bacteria, because of its N₂ fixing ability.

The appearance of a pale-yellow pellicle in semi-solid LGI-P vials inoculated with plant extracts was
an indication that the bacterium sought was present. Further purification on semi-solid LGI-P medium
showed that the pellicle rose to the surface and thickened within 7 d as reported by Boddey et al.
(1991). Streaking on solid LGI-P medium revealed the presence of minute colonies which were
initially shiny and transparent but which developed a yellow and eventually bright orange
pigmentation within 10 d. When the bacterium was streaked on Potato-P or PDA medium,
characteristic dark-brown colonies developed after about 7-10 d.

The acetylene reduction assay, although an indirect measurement of the N₂ fixing potential of isolates,
determines the presence and efficiency of the nitrogenase enzyme within the bacteria. The nitrogenase
enzyme is directly responsible for the fixation of N₂ in diazotrophic bacteria. Therefore, the
The role of diazotrophic bacteria in the nitrogen nutrition of sugar cane in Mauritius: preliminary results.  J FY Moutia et al.

Optimisation of this indirect assay has enabled not only the assessment of the N₂-fixing ability of the presumptive isolates of *Herbaspirillum* and *Gluconacetobacter* but also a comparison of their relative abilities to fix N. Although in this assay, the N₂-fixing abilities of *Gluconacetobacter* isolates were in general higher than those of *Herbaspirillum* isolates, it must be stressed that the conditions, especially the media used, were different. These results only indicate the potential of the isolates tested and in vivo and in planta studies would be the only way to confirm how and to what extent the diazotroph-plant system benefits from BNF.

**CONCLUSION**

These preliminary findings are promising since they confirm the presence of two genera of diazotrophic bacteria namely *Herbaspirillum* and *Gluconacetobacter* in local sugar cane varieties. The presence of *Gluconacetobacter* spp in Mauritius is reported for the first time in this paper. Further characterisation of both *Herbaspirillum* and *Gluconacetobacter* isolates is required to determine whether the species involved are *H. rubrisubalbicans* or *H. seropedicae* or *G. diazotrophicus*. Nonetheless, there is a clear indication that some diversity exists within local isolates. This observation augurs well for the future since diversity seems to be related to a range of N₂ fixation efficiency as demonstrated by the acetylene reduction assay in vitro. The presence of *Gluconacetobacter* in the trash of sugar cane could in the future influence the practice of sugar cane trash burning if it was shown that potentially beneficial bacteria were being destroyed. Research on BNF in sugar cane is still in its early stages and there is much work to be done to harness the whole potential of the diazotroph–plant interaction. Despite the almost worldwide distribution of *Gluconacetobacter diazotrophicus*, not all sugar cane varieties are colonised by this bacterium, indicating the specificity of the diazotroph-sugar cane association. By improving this diazotroph-sugar cane association it may provide the best prospects for developing a strategy whereby the sugar cane crop could be made to benefit significantly from BNF.

**ACKNOWLEDGEMENTS**

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The role of diazotrophic bacteria in the nitrogen nutrition of sugar cane in Mauritius: preliminary results.  *J FY Moutia* et al.


POSTHARVEST SULPHUR DIOXIDE FUMIGATION AND LOW ACID DIP FOR PERICARP COLOUR RETENTION AND DECAY PREVENTION ON LITCHI

Indoomatee Ramma
Agricultural Research and Extension Unit

ABSTRACT

Litchi (Litchi chinensis) is a tropical fruit of high commercial value. Its main postharvest problem is the rapid pericarp browning followed by decay and loss of flavour. Consequently, export of high quality litchi fruits depends exclusively on post-harvest treatments to suppress pericarp browning and disease development. The current standard treatment of litchi fruits in Mauritius is sulphur dioxide fumigation to overcome browning. This treatment bleaches the fruits which gradually turn light yellow to pink but the fruits never revert to their initial red attractive colour. To preserve and enhance peel coloration and to reduce post-harvest decay, sulphur-treated litchi fruits were dipped in different concentrations (3.5, 3.0, 2.5, 2.0 %) of hydrochloric acid solutions combined with 0.2 % Prochloraz. Sulphur treated fruits with no acid treatment, fruits treated with 3.5 % HCL alone and untreated fruits were kept as control. All acid treated fruits helped the fruits to recover an attractive bright red pericarp colour. However with dipping in 3.0 % hydrochloric acid being the most promising treatment. The latter also gave an effective control of post-harvest decay thus extending shelf life to 5 weeks under storage at 2°C and 90 - 95 % R.H as compared to 2 weeks for sulphur treated fruits that were not acid treated.

KEYWORDS: pericarp, post-harvest, sulphur dioxide fumigation, browning, acid treatment

INTRODUCTION

The litchi fruit is in high demand as an exotic commodity because of its appealing natural colour, rich taste and aroma. Its red pericarp colour is an important attribute for high quality fresh fruits. Litchi is classified among the highly perishable tropical fruit. Pericarp browning has long been considered as the main post-harvest problem of litchi (Akamine, 1960). Under ambient conditions, once harvested litchi fruits have a short post-harvest life. Unless desiccation is controlled, the bright red pericarp turns brown and brittle within 2 to 3 days. This process is accelerated by micro-cracking of the pericarp, which leads to leakage of the cytoplasm and consequent fungal infection (Underhill and Simons, 1993). These factors contribute to poor consumer appeal and hence a dramatic reduction in its commercial value.

Among the methods that have been devised to retain litchi peel colour (Holcroft & Mitcham, 1996, Ray, 1998) sulphur dioxide applied as fumigant is one of the most widely and cost effectively used methods. It helps to prevent skin browning and controls saprophytic surface fungi, two of the major post-harvest problems on harvested fresh litchi (Swarts, 1983; Zauberman et al., 1989). The sulphur dioxide treatment causes the red peel colour to be bleached to yellowish green, which is slowly and partially restored to dull yellow to pink colour after 24 to 48 hours under ambient conditions. The fruit does not revert to the original red colour. Furthermore this treatment holds no benefit for a storage period beyond 1 – 2 weeks as mould begins to develop. Sulphur dioxide interacts with the membranes, making the rind pliable and leaky to solutes. It also directly reacts with the anthocyanin rendering them colourless and stabilizing them against further degradation (Timberlake and Bridle, 1975).

In 1989, Zauberman et al reported that dipping of sulphur-treated litchi fruits in dilute acid helped to promote fruit quality and restore the red colour after bleaching. Later studies by Fuchs et al. (1993) also showed that litchi pericarp colour after sulphur dioxide treatment was significantly improved by
Postharvest sulphur dioxide fumigation and low acid dip for pericarp colour retention and decay prevention on litchi.
Indoomatee Ramma

Acid treatment. Low pH dip helps to restore the red colour to the anthocyanin, rendered colourless after sulphur dioxide treatment. The aim of this study was to develop a postharvest treatment that would restore the red colour of fruits, inhibit browning and suppress disease development. Low concentration of hydrochloric acid dip treatments after sulphur dioxide fumigation were evaluated on the pericarp colour retention, postharvest disease development and quality of litchi fruits stored at 2°C with RH 80 – 95 %. The hydrochloric acid concentrations used were 3.5 %, 3.0 %, 2.5 % and 2.0 %.

MATERIALS AND METHODS

For the litchi season 2001 – 2002, fruits of the variety Taiso, were harvested at full maturity from a commercial orchard and brought to the Laboratory within 2 hours for trial. The fruits with no defect such as cracks, insect punctures and skin tearing were selected. The fruits were then packed in ventilated crates and treated for 25 minutes with SO₂ fumes by burning of sulphur powder under a tarpaulin (@ 1 kg of pure sulphur powder / 1,600 kg of fruits), similar to the current practice adopted by local litchi exporters. The SO₂-treated bleached fruits were then aerated for one hour before being stored at 2°C. After an overnight storage at 2°C following SO₂ treatment, the fruits were divided into five different batches and 4 batches were dipped for 2 minutes in the respective concentrations of hydrochloric acid solutions: 3.5 %, 3.0 %, 2.5 % and 2.0 % (30 %HCL: water mixture made in the ratio of 1:8, 1:10, 1:12 and 1:15). The last batch was not dipped into acid. An additional batch of fruits not treated with SO₂ and acid was included in the experiment.

Preliminary studies conducted earlier showed that SO₂ treatment alone was not effective in controlling fungal growth on litchi peel. Exclusion of a fungicide resulted in development of mould mainly composed of Penicillium spp. which developed during cold storage period and spread rapidly when transferred at ambient conditions (22 – 25°C). This suggests that the pathogens are deeply embedded in, or strongly adhere to, the rough surface of the peel.

All fruits except those untreated received a fungicide, Prochloraz (tradename - Sportax) at the rate of 0.2 % for the control of mould growth. Prochloraz (Sportax) at the rate of 0.2 % was applied after SO₂ treatment or included in the acid dip solution. Each treatment was replicated 4 times with fruit samples constituting of 50 individual fruit units each.

After each acid dip treatment, 3 randomly drawn samples of 10 fruits each were analysed for total soluble solid content (TSS) and % acidity (titratable acid content). Similarly 3 equivalent samples of untreated freshly harvested fruits were also analysed. The treated samples were air dried for 10 – 20 minutes, packed in clear perforated polyethylene bags (thickness 40 µ), tied and then stored at 2°C at 85 – 95 % relative humidity.

After 2 weeks of storage fruit samples were assessed for weight loss, pericarp browning, post-harvest disease incidence and peel colour acceptability at regular weekly interval. Extent of pericarp browning was assessed using a scale of 0 – 5 as given in Table 1. The average browning index was obtained by taking the mean index of individual fruits. Fruits samples with an average index above 3 were considered commercially unacceptable. Fruits were also examined for mould development and were considered infected when a visible lesion was observed. Results were expressed as percentage of fruits infected on a 0 to 5 scale as shown in Table 1, while fruit peel colour acceptability was based on an arbitrary scale of 1 to 5 where 1 = very poor and 5 = excellent (as given in Table 1).

At each assessment, fruit aril of each sample was also evaluated for sensory attributes like, sweetness, sourness and presence of off-flavour using a group of 8 untrained panelists. The assessment was recorded on an arbitrary scale of 1 – 9, where 1=lowest (extremely weak) and 9 = highest (extremely strong).
Table 1 Scales used for quality assessment

<table>
<thead>
<tr>
<th>Pericarp browning index</th>
<th>Post-harvest disease index</th>
<th>Peel colour acceptability index</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. no browning (excellent quality)</td>
<td>0. no fruit infected</td>
<td>5 excellent</td>
</tr>
<tr>
<td>1. slight browning</td>
<td>1. &gt; 0 - 5% infected fruits</td>
<td>4 good</td>
</tr>
<tr>
<td>2. &lt; ¼ browning</td>
<td>2. &gt; 5 - 10% infected fruits</td>
<td>3 fair (acceptable)</td>
</tr>
<tr>
<td>3. ¼ to ½ browning (poor quality)</td>
<td>3. &gt; 10 – 25% infected fruits</td>
<td>2 poor (unacceptable for export)</td>
</tr>
<tr>
<td>4. &gt; ½ to ¾ browning</td>
<td>4. &gt; 25 – 50% of infected fruits</td>
<td>1 very poor (totally unacceptable)</td>
</tr>
<tr>
<td>5. &gt;3/4 browning (very poor quality)</td>
<td>5. &gt; 50% of infected fruits</td>
<td></td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Evaluation of fruit quality

PERICARP COLOUR

In general, fruits treated with SO₂ followed by acid dip resulted in better coloured fruits when compared to the control. The acid dip helped the bleached fruits to restore a bright red attractive and appealing peel colour. Furthermore no browning occurred on fruits from any of the acid treatments. (Figure 1) While, no significant difference in pericarp browning was noted between untreated fruits and fruits treated only with hydrochloric acid (3.0% for 2 minutes). Both had short shelf life as their pericarp browning index significantly increased with increased storage time (P<0.05). The fruits started to show sign of pericarp browning as from the first week of storage at 2°C and were almost of unacceptable peel colour after 3 weeks of storage. SO₂ treatment alone produced fruits with an acceptable appearance with a colour ranging from yellow to pink-red. However, during storage the rate of browning index of SO₂ treated fruits changed significantly more slowly than that of untreated fruits or fruits treated with hydrochloric dip only.

Figure 1 Changes in fruit pericarp colour during storage at 2°C, 85 – 95% relative humidity
Postharvest sulphur dioxide fumigation and low acid dip for pericarp colour retention and decay prevention on litchi.
Indoomatee Ramma

Fruit cracking

A problem associated with acid dip was fruit cracking. Micro-cracking of the pericarp may serve as entry for microorganisms and leads to leakage of fruit juice leakage and consequently fungal infection (Underhill and Simons, 1993). Preliminary observation trial showed that acid dip carried out just after SO$_2$ treatment, when the fruits were at ambient temperatures resulted in high % of cracking (27.3 %) but when the SO$_2$ treated fruits were cooled to 10°C and 2°C before acid dip, the % incidence of cracking declined from 5.2 % to 0.04% respectively (Table 2). Hence, in later experiments the fruits were cooled overnight at 2°C before acid dip treatment. With this treatment fruit cracking was not apparent visually. This showed that by lowering the fruit temperature to 2°C at the time of acid dip was effective in reducing or eliminating fruit cracking, which is an important attribute of quality.

<table>
<thead>
<tr>
<th>Fruit temperature (°C)</th>
<th>% of fruits with cracked peel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx 25 (ambient room condition)</td>
<td>27.34</td>
</tr>
<tr>
<td>10</td>
<td>5.22</td>
</tr>
<tr>
<td>2</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Effect of treatments on total soluble solids and acidity of fruit pulp

Chemical analysis of samples of litchi fruit aril before and just after acid treatments showed no significant change in total soluble solid content (TSS measured in °Brix) and % acidity (titratable acid content) (Table 3). Result obtained is in line with works carried out by Zauberman et al (1989, 1991) and Underhall and Critchley (1990) where they demonstrated very little evidence of acid penetration into the pulp after acid dip treatment and thus no remarkable effect on the eating quality.

<table>
<thead>
<tr>
<th>TSS content (°Brix)</th>
<th>% Titratable acidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean SE ± Mean SE ±</td>
<td></td>
</tr>
<tr>
<td>No treatment</td>
<td>19.20 0.16 0.48 0.02</td>
</tr>
<tr>
<td>SO$_2$ fumigated</td>
<td>20.44 0.24 0.45 0.05</td>
</tr>
<tr>
<td>SO$_2$ fumigated + 3.5 % HCl acid dip</td>
<td>19.37 0.25 0.46 0.02</td>
</tr>
<tr>
<td>SO$_2$ fumigated + 3.0 % HCl acid dip</td>
<td>18.64 0.27 0.44 0.01</td>
</tr>
<tr>
<td>SO$_2$ fumigated + 2.5 % HCl acid dip</td>
<td>19.59 0.32 0.44 0.00</td>
</tr>
<tr>
<td>SO$_2$ fumigated + 2.0 % HCl acid dip</td>
<td>19.82 0.23 0.44 0.01</td>
</tr>
<tr>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Effect of storage on quality of fruit pulp

Result of this experiment showed that both TSS and % acidity showed a general tendency to decrease with storage time. The % acidity decreased significantly (P<0.05) with increase in storage time at 2°C, while the drop in TSS content is significantly less pronounced.

Over the storage period, the differential rate of decrease in brix and % acidity leads to an increase in the sugar to acid ratio (Figure 2). This imbalance in the sugar: acid ratio is confirmed by a reduction in the eating quality as the fruits developed a bland taste, with an increase in storage time.
Effect of treatment on weight loss of fruit

During storage at 2°C, no significant difference in weight loss was observed among the different treatments (Figure 3). Weight loss increases continuously with storage time. The average % weight loss recorded after 2 and 5 weeks of storage at 2°C, RH 85-95 % were 0.8 and 1.7 % respectively.

Figure 2 Changes in mean TSS and % acidity observed in fruit aril during storage period at 2°C, 85-95 % RH.

Figure 3 Mean weight loss recorded over storage period at 2°C, RH 85-95 %.
Effect of treatments on control of postharvest diseases

Results of disease development showed that postharvest disease incidence of fruits treated S02 fumigation followed by hydrochloric acid dip with Prochloraz were significantly (p<0.05) lower compared to fruits treated with HCl and Prochloraz or fruits treated with S02 and Prochloraz (Figure 4). Untreated fruits showed high level of disease incidence (Table 4). Fruits treated with S02 and Prochloraz or HCl and Prochloraz showed significantly less infection than untreated fruits. These results agree with previous findings on litchi cv Mauritius and Red McLean (Duvenhage, 1994).

Table 4 Result of quality assessment of fruit stored for 5 weeks at 2°C, RH 85- 95 %

<table>
<thead>
<tr>
<th></th>
<th>Mean % weight loss</th>
<th>Pericarp browning index</th>
<th>Mean disease severity index</th>
<th>Peel colour acceptability index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>1.84 ns</td>
<td>5.00 c</td>
<td>4.80 e</td>
<td>1.00 d</td>
</tr>
<tr>
<td>S02 only</td>
<td>1.80 ns</td>
<td>1.82 b</td>
<td>2.20 c</td>
<td>2.46 c</td>
</tr>
<tr>
<td>HCl dip only</td>
<td>1.67 ns</td>
<td>5.00 c</td>
<td>3.00 d</td>
<td>1.00 d</td>
</tr>
<tr>
<td>S02 + 1: 8 HCl dip</td>
<td>1.53 ns</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>5.00 a</td>
</tr>
<tr>
<td>S02 + 1:10 HCl dip</td>
<td>1.60 ns</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>5.00 a</td>
</tr>
<tr>
<td>S02 + 1:12 HCl dip</td>
<td>1.85 ns</td>
<td>0.00 a</td>
<td>1.20 b</td>
<td>4.56 b</td>
</tr>
<tr>
<td>S02 + 1:15 HCl dip</td>
<td>1.66 ns</td>
<td>0.00 a</td>
<td>1.80 c</td>
<td>4.48 b</td>
</tr>
</tbody>
</table>

Values in each column not followed by the same letters are significantly different according to Duncan’s Multiple range test (p=0.05)

Fruits treated with S02 followed by HCl and Prochloraz showed a good control of mould development. Furthermore it was noted that with acid concentration of 3.5 and 3.0 % no contamination was obtained up to 5 weeks of storage at 2°C and RH 85 – 95 % but as the concentration of HCl decreased, there is indication of increase in disease index. This indicates that HCl itself has a fungistatic effect.

Figure 4 Postharvest disease severity index recorded on fruits subject to the different treatments under storage
Fruit sensory evaluation

An informal taste panel set up with 8 unexperienced panelists to evaluate quality of fruits following the different treatments showed that there was no significant difference in the sweetness and sourness index assessed after 2 weeks of storage at 2°C (Figure 5). Compared to other treatments, the mean off flavour index was found to be significantly higher for fruits treated with 3.5 % HCl alone or following S0₂ treatment. Treatment with 3.0% HCl following S0₂ treatment did not differ significantly from the untreated or S0₂ treatment or lower acid dip concentrations.

CONCLUSION

Additional treatment by HCl acid dip (3.0% for 2 minutes) resulted in fruits superior in quality as compared to application of S0₂ alone. It was found that the acid treated sulphured fruits were not prone to pericarp browning up to 5 weeks at 2°C, RH 85 – 95 %. This treatment was also useful in suppressing mould development especially at higher concentrations of acid. The addition of Prochloraz gave an even better control of disease development. Moreover, the use of S0₂, HCl and Prochloraz did not alter the eating quality of the fruits.

Further experimentation to develop recommendation for commercial application need to be carried out to determine the timing for the treatment after harvest and optimum level of HCl to be used. Possibility for identification of alternatives to fungicidal treatments has also to be undertaken.

ACKNOWLEDGEMENTS

I wish to express my thanks to Mr. Eshan Gobindram, Assistant Research Scientist, for assisting me in this experiments, Mr. R. Ramnauth, the Senior Biometrician for his support in data analysis and guidance, Mrs N.Ramburn for reviewing the manuscript and the taste panelists for the sensory evaluation.
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PROSPECTS, CONSTRAINTS, AND OPPORTUNITIES FOR FRUIT AND VEGETABLE PROCESSING IN MAURITIUS

Navindra Boodia

Agricultural Research and Extension Unit

ABSTRACT

Over the years, Mauritius has become more and more dependent on food imports for local consumption. In 2001, imports accounted for almost 69% of local food consumption. In view of decreasing dependency on food imports and increasing local production, this paper aims to review the fruit and vegetable processing sub-sector. Various prospects and opportunities are prevalent in this sub-sector in terms of possibility for import substitution, increasing demand for processed foods, increase in per-capita consumption, consumer acceptance and changing food habits, expanding tourist industry, increasing horticultural production, emerging export possibilities, and strategic location of Mauritius. Nevertheless, the fruit and vegetable processing sub-sector is still in its stage of infancy due to several constraints. These constraints have been identified as land scarcity and small horticultural holdings, high dependence on imported raw materials, poor quality and high price of raw materials, strict hygienic and sanitary exigencies, lack of technical know-how and marketing problems. To alleviate these constraints, several recommendations have been made, taking into consideration the emerging high degree of global and regional competition and the strict quality standards to be satisfied in the processed food market.

Keywords: Processed food, agro-industry, fruit and vegetable processing, Mauritius.

INTRODUCTION

The agro-industrial sector is an important sector of the Mauritian economy. The total value added at factor cost generated by the agro-industrial sector rose from Rs 2.1 billion in 1995 to Rs 2.3 billion in 1999 (CSO, 2000). In 1999, the total value added by this sector represented 2.4% of the GDP at factor cost (CSO, 2000).

Mauritius is increasingly dependent on food imports, be it for direct consumption or for processing. The food import bill rose from Rs 4.0 billion (315,000 tonnes) to Rs 7.0 billion (525,000 tonnes) between 1995 and 1999 (MCA, 2001). This represented an increase of 75% and 67% in value and volume terms respectively. Moreover, the total monetary value of the consumption of agricultural-based products turned up to be Rs. 11.8 billion in 2001, out of which 69% is imported and only 31% is produced locally (Monty, 2002a). Among the value of local production (Rs 3.7 billion), fruits and vegetables production accounted for Rs. 1.5 billion (41%) at ex-farm price (Monty, 2002a), which shows the key role of the fruit and vegetable sub-sector in the local agro-industry.

The aims of this paper are to review the local agro-industry in order to identify and discuss key prospects, opportunities, and constraints and to make recommendations accordingly. Emphasis has been particularly laid on the fruit and vegetable processing sub-sector.

OVERVIEW OF THE LOCAL AGRO-INDUSTRY

The core of the Mauritian agro-industry is structured as shown in Figure 1. Monty (2002a) has structured the local industry in a similar way, but with reference to the markets being catered for. For sake of simplicity, the structure reported by SMIDO (2002a) would be used in the present study.
The small cottage and backyard enterprises are small units, which are usually owner-managed (SMIDO, 2002a). They produce under their own local brand names and they often take advantage of market surpluses and/or seasonal availability of fruits and vegetables to process fruits and vegetables. Their production is highly seasonal and they cater for a narrow market segment. On the other hand, the large-scale enterprises are more organised and professional in their approach, catering for much larger market segments. They process fruits and vegetables all year round, although this may require imports of raw materials. Some of these enterprises also produce under franchise (SMIDO, 2002a).

The local agro-industry consists mainly of enterprises manufacturing animal-based products, sugar-based products and/or fresh flowers (Table 1). The Ministry of Industry and Industrial Technology (1990) revealed that only 7.4% of registered enterprises process fruits and vegetables. In the latter study, it was also reported that the workforce in the fruit and vegetable-processing sub-sector comprises only 5.4% of the total workforce in the agro-industrial sector. In 2002, only (5.9%) of small and medium enterprises (SME) registered at the Small and Medium Industries Development Organisation (SMIDO) were involved in fruit and vegetable processing. These clearly illustrate the fairly poor representation of fruit and vegetable processing in the local agro-industrial sector.

Table 1 Product group, number of enterprises and workforce in the Mauritian agro-industry

<table>
<thead>
<tr>
<th>Product group</th>
<th>% of total number of enterprises</th>
<th>% of total workforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthurium and other flowers</td>
<td>30.6</td>
<td>6.0</td>
</tr>
<tr>
<td>Poultry, fish, crustaceans, molluscs and processing of meat and fish</td>
<td>23.1</td>
<td>28.3</td>
</tr>
<tr>
<td>Confectionery, chocolates, biscuits and cake preparations</td>
<td>10.2</td>
<td>6.5</td>
</tr>
<tr>
<td>Beverages (alcoholic and non-alcoholic)</td>
<td>9.3</td>
<td>29.6</td>
</tr>
<tr>
<td>Tea, spices, pepper, vanilla, ginger, and turmeric</td>
<td>8.3</td>
<td>8.3</td>
</tr>
<tr>
<td>Vegetables and fruits (prepared or preserved), jams, marmalades, fruit juices</td>
<td>7.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Edible oil, margarines, butter, ghee and dairy products</td>
<td>6.5</td>
<td>6.6</td>
</tr>
<tr>
<td>Others (5 different product groups)</td>
<td>4.6</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Adapted from: Ministry of Industry and Industrial Technology (1990)

FRUIT AND VEGETABLE PROCESSING SUB-SECTOR

A census conducted by Boodia and Nallee (2002) revealed that 35 enterprises were involved in fruit and vegetable processing. However, it is estimated that 6-8 enterprises might not have been covered by the study because they were not registered. Most fruit and vegetable processors fall in the product category of pickles, jam, jelly, marmalade and crystallised fruits/fruit bars, and ground spices and curry powder (Table 2).

LOCAL PRODUCTION OF PROCESSED FRUITS AND VEGETABLES

The production output of preserved fruits, preserved or prepared vegetables and fruit and vegetable juices has remained fairly stable from 1991 to 2001 (Figure 2a, b and c). In 2001, the production output represented 13.4%, 14.0% and 11.7% of total domestic utilisation for preserved fruits, preserved or prepared vegetables and fruit and vegetable juices respectively. These figures clearly show the low production output of processed fruits and vegetables.
**Table 2** Fruit, vegetable and spice processors in Mauritius (2002)

<table>
<thead>
<tr>
<th>Product category</th>
<th>Number*</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickles (including paste, ketchup and sauce)</td>
<td>22</td>
<td>62.9</td>
</tr>
<tr>
<td>Jam, jelly, marmalade and crystallised fruits / fruit bars</td>
<td>15</td>
<td>42.8</td>
</tr>
<tr>
<td>Ground spices and curry powder</td>
<td>13</td>
<td>37.1</td>
</tr>
<tr>
<td>Juice / nectar</td>
<td>5</td>
<td>14.3</td>
</tr>
<tr>
<td>Chips and crisps</td>
<td>4</td>
<td>11.4</td>
</tr>
<tr>
<td>Canned vegetables and fruits</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td>Others (party cakes, minimal processing, and mayonnaise)</td>
<td>3</td>
<td>8.6</td>
</tr>
</tbody>
</table>

* An enterprise can be involved in one or more categories of processed products. Hence, total does not equal to the total number of food-processing enterprises in Mauritius. Source: (Boodia and Nallee, 2002 unpublished)

**Figure 2** Production output, gross imports, gross exports, and total domestic utilisation (Adapted from: CSO, 1992-2002)

The main categories of locally processed products include: jam, jelly, marmalade, canned pulses and vegetables, tomato ketchup and sauce, chilli sauce, chili paste and a vast range of fruit and vegetable pickles (Business Magazine, 1999). However, other categories of processed foods are also produced locally by the small cottage and backyard enterprises. The range is so diverse that it is practically impossible to mention all of them in this paper.
Prospects, constraints, and opportunities for fruit and vegetable processing in Mauritius. Navindra Boodia

Imports of processed fruits and vegetables

A very wide range of processed fruits and vegetables is imported. Gross imports of preserved fruits, preserved or prepared vegetables and fruit and vegetable juices on a volume basis have been summarised in Figure 2a, b and c above. From 1991 to 2001, there has been an increase of 194%, 423% and 17.8% in gross imports of preserved fruits, preserved and prepared vegetables and fruit and vegetable juices respectively. According to Figure 2b gross imports of processed vegetables are increasing at a high rate. For processed tomato only, the imported volume rose by 44% from 850 tonnes in 1995 to 1 221 tonnes in 1999 (MCA, 2001). This trend of rising imports has also been noticed for tomato ketchup, preserved mushrooms, chilli sauce and some other major processed food, including frozen vegetables.

PROSPECTS AND OPPORTUNITIES FOR PROCESSING

Despite the fairly low production outputs (Figure 2a, b and c) of the fruit and vegetable processing sub-sector in Mauritius, there is ample scope for its future development. Its future scope will be influenced by import substitution, demand for processed foods, increase in per-capita consumption, consumer acceptance and changing food habits, expanding tourist industry, increasing horticultural production, export possibilities, and strategic location of Mauritius.

Import substitution

As discussed above, Mauritius is highly dependent on imports of preserved fruits and vegetables. Demand for these products are likely to increase in the future, following the trends observed in Figure 2a and b. In view of import substitution, prospects do exist for processing of fruits and vegetables locally. Strategies need to be formulated in order to address this issue. However, after the removal of global trade barriers, some of these products may become less expensive, thereby affecting profit margins of local producers. Therefore, the possible effects of trade globalisation need to be addressed from the very start, prior to implementing any policy decisions for import substitution.

Demand for processed foods

Not all processed foods receive easy acceptance from local consumers. Processed chillies, tomatoes, Agaricus mushrooms, garden peas, red beans and frozen vegetables are widely accepted by local consumers. For instance, consumption of processed tomatoes is already substantial in Mauritius. In 1998, consumption of processed tomato amounted to about 4 Kg of fresh tomato equivalent per capita, which is about one quarter as much as fresh tomato consumption (MSIRI, 1998).

However, for some commodities like onions, the fresh form is still preferred. A study conducted by Newaj (2001) showed that 99% of hotels and restaurants were not willing to purchase locally processed onions, as they prefer to process their own onions.

Increase in per-capita consumption

From 1995 to 2001, there has been a gradual increase in per-capita consumption of both preserved fruits and prepared or preserved vegetables, while only a slight increase in per-capita consumption of vegetable and fruit juices was recorded (Figure 3). With rising standard of living and consumer awareness for healthy lifestyle, consumption of fruit and vegetable juices are likely to increase and eventually their demand.
Prospects, constraints, and opportunities for fruit and vegetable processing in Mauritius. Navindra Boodia

Figure 3 Per-capita consumption of preserved fruits, fruit and vegetable juices, and preserved or prepared vegetables. (Source: CSO, 1995-2002)

Consumer acceptance and changing food habits

Consumer acceptance is much dependent on traditional food habits. Having their own cuisine, the average Mauritian consumers are not willing to buy processed vegetables, except those, which were existent long ago, for example chilli paste and the traditional Indian pickles. Nevertheless, over the recent years pre-cooked and / or pre-prepared foods have been becoming increasingly popular, since little time is available for food preparation at home (Business Magazine, 1999). Increasing trend towards the consumption of convenience foods (soup and salad packs and stir fry mixtures) is creating a growing market for these products (SMIDO, 2002a). Hence, ample scope exists for minimal processing.

Moreover, with an increasing standard of living, Mauritians will be willing to purchase a variety of novel food products, including processed fruits and vegetables. For instance, 70% of local supermarkets interviewed by Newaj (2001) showed their interest to sell onions preserved in vinegar, for which no market existed in Mauritius a decade ago.

Expanding tourist sector

According to the Ministry of Tourism (1999), tourist arrivals have increased from 291 550 in 1990 to 578 085 in 1999 (equivalent to a 98.3% increase). The tourist sector is thus booming. Subsequently, the demand for food will be greater, including processed fruits and vegetables. A tourist consumes on average 3.8 times the amount of fruits and vegetables consumed by an average Mauritian (Table 3). The number of tourist nights spent in Mauritius has been increasing year after year and in 1999, it has reached an all-time high of 5 729 464 nights (Ministry of Tourism, 1999). Based on this figure, it was calculated that the local food industry should cater for the supply of fruits and vegetables for an additional 59 650 local inhabitants.
Table 3  Consumption of some fruits and vegetables by local inhabitants and tourists (1996)

<table>
<thead>
<tr>
<th>Fruits / vegetables</th>
<th>Consumption in g day⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local inhabitant</td>
</tr>
<tr>
<td>Banana</td>
<td>21</td>
</tr>
<tr>
<td>Potatoes</td>
<td>48</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>25</td>
</tr>
<tr>
<td>Onions</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>124</td>
</tr>
</tbody>
</table>

Increasing horticultural production

Over the recent years, fruit and vegetable production has been increasing (CSO, 1992-2002). Presently, we are self-sufficient in fresh vegetables and tropical fruits. However with the implementation of the Midlands Dam project and with the release of sugar land for horticultural production, there is a strong possibility of overproduction, which could result in decrease in prices and farmer’s incomes. In such circumstances, grower cooperatives may opt for processing as a means to add value to their produce.

Export possibilities

Most local food processing enterprises supply the local market. Only a few (17.1%) export their processed commodities to Madagascar, Reunion, Germany, Italy, France, Australia, Canada, Seychelles, and Rodrigues (Boodia and Nallee, 2002). Processed food items being exported include pickled fruits and vegetables, processed chillies, curry powder and fruit bars (SMIDO, 2002a). According to Business Magazine (1999), one fruit and vegetable processing enterprise exports most of its production (80%). There is thus a possibility for other local enterprises to export their processed commodities. However, high quality and competitive price need to be met to access the international market. Quality in this market has always included purity, colour, size, texture, flavour, and consistency (Kelly, 1988). Nutritional composition is also becoming increasingly important to the consumers in developed countries according to Kelly (1988).

With the opening of new markets like Southern Africa Development Community (SADC), Common Market for Eastern and Southern Africa (COMESA), and African Growth and Opportunity Act (AGOA), Mauritius has the opportunity to export towards African and American countries. Both the SADC and COMESA are free trade areas for Mauritius, whereby our products would be waived from custom duties, thus enabling our products to compete with imported products from non-member countries.

The ethnic and speciality food market is developing rapidly in Europe. Seven million ethnic meals are served every day in France only (Anon 2002). One new restaurant out of two in Paris develops an ethnic cuisine concept and all hyper and supermarket chains have developed large shelves of ethnic foods. The European ethnic food market has increased in size by 37% from 1998 to 2001, which is equivalent to a value Rs. 148 billion (Anon., 2002). Ethnic foods are now consumed by all socio-styles, irrespective of age group. European tourists who have visited Mauritius already have a taste of our culture and thus there may be enormous opportunities to export Mauritian ethnic foods to Europe.

Strategic location

By virtue of its strategic location, modern logistics, expertise and know-how in the agro-processing sectors, Mauritius should take advantage of the various resources available in neighbouring African countries to satisfy local needs and to develop the Mauritian agro-processing sector (MCA, 2001). The region can be made our production base and Mauritius could be developed as an agro-processing hub (Monty, 2002b), thus taking advantage of our competitive edges vis-à-vis countries in the region. Subsequently, semi-processed raw materials can be imported cheaply from countries like Madagascar and Mozambique to be further processed and marketed.
CONSTRAINTS TO FRUIT AND VEGETABLE PROCESSING

The above-mentioned factors should have resulted in a flourishing fruit and vegetable-processing sub-sector. However, this sub-sector still lags behind due to several constraints, which are discussed hereunder.

Land scarcity and small horticultural holdings

Mauritius is a small island, whereby 48% of the island acreage is devoted to sugar cane cultivation. Competition for arable land between the sugar and non-sugar sectors results in restricted land acreage for horticultural production. This may limit the expansion of the horticultural production in Mauritius. Moreover, most horticultural holdings are of small acreage, which does not favour mechanisation and economies of scale. As a result, cost of local raw materials are high and hence food processors prefer to have recourse to imported raw materials.

High dependence on imported raw materials

Raw materials for the local agro-industry are generally imported. Monty (2002b) reported that there is a high dependency on imports of raw materials for the local agro-industrial sector. However, in the fruit and vegetable processing sub-sector, most SMEs acquire their raw materials locally.

The latter sub-sector currently processes a mere 5% of the domestic horticultural production and is lagging behind as compared to a number of developed countries and to Reunion Island where some 70 and 30% of horticultural production are processed respectively (MCA, 2001). The high dependence on imported raw materials (Monty, 2002b) clearly constitutes a major drawback to the development of a viable agro-industrial sector since our processed products may not be price-competitive.

Poor quality and high price of raw materials

The quality of local raw materials is generally low due to the mismanagement of cultural practices at both the production and post-production levels. Generally, local fresh products are not graded and they are likely to contain high agro-chemical residues. Moreover, market uncertainties, price fluctuations, handling and storage problems do prevail, limiting the expansion of the fruit and vegetable processing sub-sector. Similar problems were reported in Turkey, when they sought to develop their processing industry. To resolve these, the producers and the processing industry came together in contract farming organisations (Güngör et al., 2000). In Mauritius, similar organisations may have to be encouraged for some horticultural commodities.

The high price of local raw materials has compelled agro-processing industries to turn entirely to imported raw materials (MCA, 2001). In the eighties, an established large-scale food processor has tried to export frozen green beans, pineapple pulp and marmalade (Anon., 1991). But, this activity had to stop because they were not able to get the raw material at a low enough price to be competitive on the world market.

Hygienic, sanitary and Food Act exigencies

Hygienic and sanitary norms in the food sector have negatively affected several enterprises, so much so that some of them have stopped operating over the recent years. Boodia and Nallee (2002) have reported that a considerable percentage (31%) of enterprises (particularly newly set enterprises) have found that the Food Act is too rigid and demanding. The main constraints faced due to the implementation of the latter act are: difficulty in acquiring permits of operation, production unit not conforming to the pre-set norms and lack of labelling facilities. However, the implementation of the Food Act should not be regarded as a drawback, since it ensures that processed foods are of an acceptable quality to be marketed. To develop an outward looking approach in the agro-industrial sector, food quality and safety norms need to be consolidated and be further fine-tuned. In this respect, the Food Act would act as a baseline.
Lack of technical know-how

Lack of technical expertise in the field of fruit and vegetable processing also limits the development in this sub-sector. SMEs suffer the most from the lack of technical know-how. The main technical problems faced by these enterprises are: lack of expertise to determine shelf life; short product shelf life; lack of know-how on packaging and presentation of their products; and little knowledge on semi-industrial processing equipment. Therefore, institutional support would be of prime importance to the SMEs in terms of technical know-how and expertise.

Marketing problems

Uncertain and narrow markets act as an important deterrent to local production of processed vegetables. According to Boodia and Nallee (2002), 20% of local enterprises have claimed to face fierce competition from the imported products, while 14% have faced problems in selling their products. This may be attributed to low product quality and lack of market intelligence. The lack know-how in this field is highly felt and yet no local institution is catering for this discrepancy.

CONCLUSION & RECOMMENDATIONS

The agro-industrial sector can cater for both the local and export markets, reducing imports as well as generating greater foreign currency earnings. Presently, the agro-industrial sector mainly consists of animal-based and sugar-based processing as well as fresh flower trade. As such, the fruit and vegetable processing has not really taken off, despite numerous prospects and opportunities that are prevalent in the sector. In fact the agroindustrial sector is still lagging behind other sectors of the Mauritian economy due to several constraints. To alleviate these constraints, the following recommendations would be made:

- Import substitution strategies have to be formulated in view of encouraging price-competitive local production and discouraging products which are not price-competitive;
- Mauritian and Rodriguan ethnic foods need to be further developed with respect to the standardisation of production protocols and their quality attributes;
- Intensive horticultural production systems, using high yielding varieties have to be set up. Variety evaluation trials should identify varieties with high processing potential;
- Conditions for imports of semi-processed raw materials from the region have to be favoured and in such a way that it does not affect local production negatively;
- Contract-growing has to be favoured between growers and processors, whereby the growers supply the processor at an agreed price, volume and quality standards;
- On a medium and larger scale of production, light and selected mechanisation can be sought to alleviate the high labour cost problem, thereby reducing cost of production;
- Clustering of small and medium enterprises can reduce cost of production and take advantage of economies of scale. The clustering project under the aegis of the NPCC may be of great help and it should be further enforced;
- Food quality and safety standards for processed fruits and vegetables have to further fine-tuned, taking the Food Act as a baseline, with the eventual aim of satisfying international food quality and safety norms;
- Investment in high-tech economically viable systems to produce high quality products, satisfying the norms set-up by the international market needs to be encouraged;
- SMEs should seek technical know-how and expertise from local institutions and if necessary from abroad. The Technology Introduction and Development Scheme could provide, in part, the required consultancy services to address their technical problems;
- Institutional support in terms of market intelligence and development of marketing strategies for both the local and export market needs to be provided. Export niche marketing strategies should also be formulated;
- Innovation in terms of new product development should not be overlooked. Research and development and its implementation, monitoring and control in fruit and vegetable processing should be an on-going process with feedback loops;
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Prospects, constraints, and opportunities for fruit and vegetable processing in Mauritius. Navindra Boodia


QUALITY ATTRIBUTES OF MARQUISE STRAWBERRY VARIETY

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ABSTRACT

Local production of fresh strawberries has been increasing to satisfy local consumers and tourists. Maturity at harvest is important in determining fruit quality. In Mauritius, local growers harvest strawberries before they are fully ripe. No scientific investigation has been carried out to evaluate the effect of this practice on quality. In this context, this study was conducted to analyse the effect of fruit maturity at harvest on the quality parameters of strawberry cultivar (Marquise). Strawberries were harvested at three maturity stages namely: ½ to ¾ ripe, ¾ ripe to fully ripe and fully ripe. A trained panel was used to characterize and assess sensory attributes. Total soluble solids and firmness were measured instrumentally. Ascorbic acid content was determined by titration with dichlorophenolindophenol dye. Results show that fully ripe strawberries had highest ratings for flavour, sweetness and juiciness, total soluble solids content (8.60 ± 0.837 %) and ascorbic acid content (21.37 ± 3.220 mg / 100 g). On the other hand, ½ to ¾ ripe strawberries obtained highest ratings for crispness and hardness, and firmness values (0.50 ± 0.108 N cm⁻²). This study has demonstrated that fully ripe Marquise strawberries have optimum flavour, sweetness and juiciness, which are strong determinants of fruit quality. Harvesting strawberries when ¾ to fully ripe may therefore result in sub-optimal attributes.

Keywords: quality, strawberries, maturity, sensory attributes

INTRODUCTION

The main strawberry varieties grown locally are Tiobelle, Marquise and Tioga which are mainly short day varieties produced over an acre of two hectares with an average yield of 7 – 8 t ha⁻¹ for Marquise, and 8 – 9 t ha⁻¹ for Tioga and Tiobelle, (Lutchoomun, 2001). Importation of this high value commodity was 25 tons for the year 2000 to meet increasing demand of local consumers and tourists (Ministry of Trade and Shipping, 2000). For the local strawberry growers to be able to sell their produce and satisfy consumers, strawberries need to be of good quality. The International Organisation for Standardisation defines “quality” as “the degree to which a set of inherent characteristics fulfills requirements” (ISO 2000). Requirements also include consumer expectations. (Kader 1999) defined quality of fresh fruits as a combination of attributes, properties, or characteristics that give each commodity value in terms of human food. These characteristics include sensory attributes such as firmness, appearance and flavour, as well as nutritional value and health benefits (Kader 1999). Sensory attributes are therefore important aspects of fruit quality and can best be assessed by consumers who are the final arbitrators of quality. Sensory methods involving the use of trained panels and / or consumers panels have been used in research carried out in various countries to investigate the sensory characteristics of strawberry cultivars, quality problems and consumer acceptability of strawberries (Ford et al. 1997, Haffner et al. 1997, Perez et al. 1997, Hoberg et al. 1997, Shamaila et al. 1992, Kidmose et al. 1996, Reitmeier et al. 1991, Carlen et al. 2001, Ulrich et al. 1997). Some studies have also focused on establishing relationships between instrumental measurements and sensory attributes to determine simple, rapid and objective monitoring methods which would be used routinely as “quality markets (Wozniak et al. 1997, Kidmose et al. 1996, Carlen et al. 2001, Cheryll et al. 1991). These are required for monitoring of sensory characteristics to measure the outcome of research on new varieties and methods of production, and the effectiveness of pre and post harvest practices to ensure quality. According to (Kader 1999), maturity at harvest is the most important factor that determines storage life and final fruit quality. Objective indices of maturity for strawberries based on surface colour are
Quality attributes of marquise strawberry variety. R S Munbodh and B E Aumjaud

included in mandatory standards (Kader, 1999). However, there are no local standards, which cover minimum maturity indices for strawberry cultivars. Informal feedback from local growers and a study carried out by (Proag 1990) indicate that strawberries are mostly harvested at the three quarter to fully ripe stage to provide some marketing flexibility. Strawberries are non-climacteric fruits and (Kader 1999) recommended that they should be picked when fully ripe to ensure good flavour, which is an important determinant of overall quality. No scientific investigation has been carried out in Mauritius to determine the implications of harvesting strawberry cultivars before they are fully ripe for sensory quality and consumer acceptability. This study aims at using sensory evaluation and instrumental measurements to analyse the effect of maturity at harvest on the quality parameters of Marquise strawberry cultivar. It constitutes pioneering work on characterization and quantification of sensory attributes of local fruits by a trained panel and could form the basis for further studies involving consumer panels.

MATERIALS AND METHODS

Strawberry samples

Marquise strawberry cultivar was harvested from first year-established plantations at Wooton and Curepipe Crop Research Centres, at different stages: ½ ripe, ¾ to fully ripe, fully ripe. The classification was based on surface colour, which was visually assessed using an established colour chart from the Royal Horticultural Society of U.K (The Royal Horticultural Society, 1998). The fruits were collected in the middle row of the plantations and sorted for uniformity in size and red colour distribution.

Sensory evaluation

Quantitative descriptive analysis, also known as profiling method, was used for sensory evaluation. It involves the detection and description of both quantitative sensory aspects of food by trained panels (Meilgaard et al. 1991). All analyses were carried out on the day of harvest. Panelists were from the Agricultural Research and Extension Unit. They were selected based on their sensory acuity, their sensitivity and ability to discriminate between small differences in intensity of a sensory attribute. The vocabulary was formulated from scratch by the panelists who suggested and agreed on descriptive terms to characterize the fruit. The outcome of two replicate sensory evaluation sessions performed by 6 trained panelists was considered. Samples of each maturity stage consisting of 3 berries were evaluated for aroma, hardness, juiciness, crispiness, flavour, sweetness, sourness, bitterness and sourness after-taste. Such fruit samples was cooled and presented on white polystyrene plates. Each attribute was score for intensity using a 10cm unstructured line scale with anchored terms at both ends. The panelists indicated the intensity of each attribute by placing a vertical line on the scale. Quantification of the results was obtained by measuring the distance from zero to the vertical line.

Physical and chemical analysis

For each maturity stage, three replicates consisting of 6 berries were used for the determination of total soluble solids content. The fruits were thoroughly crushed with a pestle and mortar, and filtered through muslin cloth. The extracted juice was used for measurement of total soluble solids content using an Atago hand refractometer (Manufacturer, country, United Kingdom). Ascorbic acid determination was carried out according to the AOAC method (1990) involving titration with dischlorophenol indophenol dye. Triplicate determinations were performed for each maturity stage. Firmness was measured using a Model dynamometer (Ctift, France). It was expressed as Newton (N) cm². 20 berries were used for each maturity stage.

Statistical analysis

The sensory data was analysed by two-factor ANOVA with replication at 5%, 1% and 0.1% levels. When significant differences in mean ratings were noted for samples, the LSD test at 5% level was applied to determine which sample means were different. The significance of sample-panelist
interaction was also assessed. In the case of total solids content, ascorbic acid content and firmness values, single factor ANOVA and the LSD test at 5% level was used.

RESULTS AND DISCUSSION

**Table 1** Ratings for sensory attributes of Marquise strawberry variety at different maturity stages

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Mean ratings</th>
<th>Significance of difference among maturity stages</th>
<th>Significance of panelist-sample interaction</th>
<th>LSD value (p = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>½ to ¾ ripe</td>
<td>¾ to fully ripe</td>
<td>Fully ripe</td>
<td></td>
</tr>
<tr>
<td>Aroma</td>
<td>3.49±</td>
<td>5.73±</td>
<td>6.58±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>2.15b</td>
<td>2.07a</td>
<td>1.78b</td>
<td></td>
</tr>
<tr>
<td>Juiciness</td>
<td>5.29±</td>
<td>5.00±</td>
<td>7.79±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>1.48b</td>
<td>2.22b</td>
<td>0.80b</td>
<td></td>
</tr>
<tr>
<td>Crispiness</td>
<td>8.05±</td>
<td>6.17±</td>
<td>6.07±</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>1.14a</td>
<td>1.62b</td>
<td>1.89b</td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>6.76±</td>
<td>3.92±</td>
<td>2.83±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>1.79a</td>
<td>1.82b</td>
<td>2.30b</td>
<td></td>
</tr>
<tr>
<td>Sweetness</td>
<td>4.08±</td>
<td>5.05±</td>
<td>8.16±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>1.30b</td>
<td>2.06b</td>
<td>0.98b</td>
<td></td>
</tr>
<tr>
<td>Soursness</td>
<td>5.58±</td>
<td>5.30±</td>
<td>1.72±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>3.07a</td>
<td>1.86a</td>
<td>1.35b</td>
<td></td>
</tr>
<tr>
<td>Bitterness</td>
<td>0.11±</td>
<td>0.27±</td>
<td>0.07±</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.25a</td>
<td>0.66b</td>
<td>0.18b</td>
<td></td>
</tr>
<tr>
<td>Strawberry flavour</td>
<td>4.44±</td>
<td>4.36±</td>
<td>7.09±</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>1.67b</td>
<td>2.52b</td>
<td>1.49b</td>
<td></td>
</tr>
<tr>
<td>Soursness after-taste</td>
<td>3.80±</td>
<td>2.75±</td>
<td>1.43±</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>2.62a</td>
<td>2.32a</td>
<td>1.66a</td>
<td></td>
</tr>
</tbody>
</table>

± Standard deviation

Ratings were analysed by two-way ANOVA with replication, followed by LSD test (5% level).

n.s. non-significant

* p < 0.05

** p < 0.01

*** p < 0.001

Common superscripts between columns represent no significant difference.

**Table 2** Instrumental measurements of firmness of Marquise strawberry variety at different maturity stages

<table>
<thead>
<tr>
<th>Maturity stage</th>
<th>Average Firmness (N cm⁻²)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to ¾ ripe</td>
<td>0.50 ± 0.108a</td>
<td></td>
</tr>
<tr>
<td>¾ to fully ripe</td>
<td>0.37 ± 0.063b</td>
<td></td>
</tr>
<tr>
<td>Fully ripe</td>
<td>0.31 ± 0.075b</td>
<td></td>
</tr>
</tbody>
</table>

† Standard deviation

Firmness values were analysed by one-way ANOVA (5% level), followed by LSD test (5% level).

Common superscripts between rows represent no significant difference.
Quality attributes of marquise strawberry variety. R S Munbodh and B E Aumjaud

Table 3  Total soluble solids of Marquise strawberry variety at different maturity stages

<table>
<thead>
<tr>
<th>Maturity stage</th>
<th>Average Total soluble solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to ¾ ripe</td>
<td>7.06 ± 0.171^c</td>
</tr>
<tr>
<td>¾ to fully ripe</td>
<td>7.69 ± 0.675^b</td>
</tr>
<tr>
<td>Fully ripe</td>
<td>8.60 ± 0.837^a</td>
</tr>
</tbody>
</table>

^ Standard deviation

Total soluble solids values were analysed by one-way ANOVA (5% level), followed by LSD test (% level). Common superscripts between rows represent no significant difference.

Figure 1  Radar diagram of selected sensory attributes of Marquise strawberry variety at different maturity stages

The distance from the center is the mean value for a sensory attribute. The arrangement of attributes around the center point is for convenience only.

Table 4 Ascorbic acid content of Marquise strawberry variety at different maturity stages

<table>
<thead>
<tr>
<th>Maturity stage</th>
<th>Average Ascorbic acid (mg / 100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to ¾ ripe</td>
<td>15.23 ± 1.985^c</td>
</tr>
<tr>
<td>¾ to fully ripe</td>
<td>18.83 ± 2.256^b</td>
</tr>
<tr>
<td>Fully ripe</td>
<td>21.37 ± 3.220^a</td>
</tr>
</tbody>
</table>

^ Standard deviation

Ascorbic acid content was analysed by one-way ANOVA (5% level), followed by LSD test (5% level). Common superscripts between rows represent no significant difference.
Sensory Profile

Table 1 reveals the sensory attributes which were identified by the panelists. The mean ratings for the three maturity stages were found to be significantly different in the case of aroma, juiciness, hardness, sweetness, sourness and strawberry flavour (p < 0.001). For crispness, the mean ratings were significantly different at 1% level while for bitterness and sourness after-taste, the mean ratings differed significantly at 5% level only. The data presented in Table 1 also show that sample-panelist interaction was not significant for all attributes except sourness and bitterness. This would tend to suggest that the identified sample differences were due to real differences among the various maturity stages for 7 out of 9 sensory attributes. Sensory profiles were generate for the attributes with significantly different mean ratings at 0.1% level and no significant sample-panelist interaction namely aroma, strawberry flavour, sweetness, hardness and juiciness. They are depicted by the radar diagram in Figure 1. The outcome of the statistical analysis (Table 1) and visual differences observed from the sensory profiles (Figure 1) demonstrate that strawberries harvested at the fully ripe stage obtained highest mean ratings for flavour, sweetness and juiciness. Interestingly, Table 1 shows that the attributes of “¾ to fully ripe” strawberries were similar to “fully ripe” strawberries for aroma, crispness and hardness, and similar to “½ to ¾ ripe” strawberries in the case of juiciness, sweetness and flavour (p > 0.05). Table 1 and Figure 1 clearly establish that “½ to ¾ ripe” strawberries obtained the lowest ratings for aroma but highest ratings for crispness and hardness attributes (p < 0.05).

Physical and Chemical Characteristics

Table 2 shows that fruit firmness decreased in the following order: “fully ripe” < “¾ to fully ripe” < “½ to ¾ ripe”. On the other hand, Table 3 and Table 4 indicate a reverse trend for total soluble solids and ascorbic acid content. “Fully ripe” strawberries obtained highest mean values while “½ to ¾ ripe” strawberries obtained lowest mean values for these two characteristics.

DISCUSSION

Marquise strawberries harvested at the fully ripe stage had most intense flavour, sweetness and juiciness compared to “¾ to fully ripe” and “½ to ¾” ripe strawberries. Correlation of sensory attributes of strawberry cultivars grown in Denmark showed that sweetness was positively correlated with strawberry flavour (Kidmose et al. 1996). In the present study, fully ripe Marquise strawberries obtained highest scores for both flavour and sweetness. Interestingly, (Ford et al. 1997) reported that flavour, sweetness and juiciness were the attributes, which experienced fruit tasters stated as contributing most to strawberry quality. Furthermore, a survey carried out to examine Californian consumers’ perceptions of fruit quality revealed that consumer complaints for strawberries centred around lack of flavour (Bruhn et al. 1991).

Marquise strawberry variety harvested when fully ripe also obtained highest total soluble solids content. (Haffner et al. 1997) established that best overall fruit quality was fond in the Canadian strawberry cultivar with the highest flavour scores and soluble solids content. (Kader 1999) recommended a minimum soluble solids content of 7% for acceptable quality of strawberries. This minimum value was achieved by the Marquise strawberries at the three maturity stages. However, no tolerances of deviation are specified for the minimum soluble solids proposed by (Kader 1999). In view, of the large variation among cultivars, production areas and seasons, no inferences can be made with respect to consumer acceptability level of Marquise strawberries based on the total soluble solids content.

The mean ascorbic acid content of Marquise strawberries at the various maturity stages varied between 15 – 21 mg / 100g. Ascorbic acid content has been shown to vary widely among cultivars. (Haffner et al. 1997) measured amounts of 30 – 70 mg / 100g in fifteen strawberry cultivars. In another trial involving twelve strawberry cultivars, (Kidmose et al. 1996) reported a variation of 35 – 75mg / 100g. The ascorbic acid content obtained for fully ripe Marquise strawberries is on the low side. (Kidmose et al. 1996) also found one sweet cultivar with a strong strawberry flavour but low ascorbic acid content. Instrumental measurements of firmness indicated that “fully ripe” strawberries were less firm than the “¾ to fully ripe” strawberries. This observation is in line with literature reports that maturity is a factor which affects texture attributes including firmness and could be explained by loss of turgor, degradation of starch and breakdown of cell walls (Spayd 1981). Fruit firmness is a characteristics that is especially important in fruit varieties that are to be mechanically harvested or that have to travel long transportation distances, in order to preserve the fruit texture during post-harvest handling. The sensory...
attribute hardness was quantified by the panelists. However, they did not detect any differences in hardness between the “fully ripe” and “¾ to fully ripe” strawberries. This could be explained by differences which were too small to be detected by the panelists.

CONCLUSION

Maturity stage at harvest influenced the sensory profiles, total soluble solids content, ascorbic acid content and firmness of Marquise strawberry variety. Optimum flavour, sweetness and juiciness were observed when strawberries were harvested fully ripe. The local practice of harvesting strawberries at “¾ to fully ripe” stage may therefore result in less than optimum quality. The only advantage of harvesting the fruit before it is fully ripe is that it is firmer and may resist damage during handling. The current practice among local growers provides some marketing flexibility but fails to ensure attainment of optimum sensory attributes, which are strong determinants of strawberry quality. However, further studies involving local consumer panels need to be carried out to related consumer acceptability with maturity at harvest and determine minimum maturity required for consumer satisfaction. Effective management of post-harvest handling and consumer handling practices will then be necessary to maintain the optimum quality attained at harvest.

Sensory evaluation is a valuable tool in research on fruit quality. It has good potential for further research and development on the quality of locally produced strawberries. Some recommendations for future research involving sensory methods are:

- Consumer studies aimed at relating maturity indices at harvest to the final consumer acceptability of strawberry varieties
- Characterisation and evaluation of the sensory profiles of other locally produced strawberry varieties.
- Development of local standards for minimum acceptability level based on consumer requirements or expectation of quality.
- Investigation of relationships between instrumental measurements and sensory attributes to develop simple and rapid methods for monitoring of sensory quality during production or research on new varieties.
- Carrying out the cost benefit analysis of harvesting strawberries

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MINISTRY OF TRADE AND SHIPPING. 2000. Personal communication.


PERFORMANCE OF NEW STRAWBERRY VARIETIES USING COLD-STORED AND FRESH RUNNERS

S Lutchoomun

Agricultural Research & Extension Unit

ABSTRACT

Two trials were conducted at Wooton Crop Research Station in view of screening high yielding strawberry varieties suitable for local conditions and for extending the production season. The first trial consisted of evaluation of 14 varieties namely Agathe, Anabelle, Angelina, Anthea, Camarosa, Cigaline, Cijosée, Ciloe, Cirano, Cireine, Diamante, Eros, Honeoye and Oso Grande using cold stored runners imported from France. The varieties Angelina, Anthea, Cigaline, Ciloe, Cireine, Eros and Honeoye had poor overall marketable yield and keeping quality whereas Anabelle, Camarosa and Cirano were poor producers of runners. Varieties Agathe, Cijosée, Diamante and Oso Grande were evaluated in a second trial with two locally cultivated varieties namely Marquise and Sequoia, using locally produced fresh runners. Agathe gave the highest marketable yield (508 g/plant) followed by Oso Grande (360 g/plant). Diamante had significantly lower yield but produced the largest fruits (13.3g). The varieties Agathe, Cijosée, Diamante and Oso Grande were also promising in terms of early bearing habit, attaining 50% harvest one to two weeks before the locally grown varieties.

Key words: Strawberry varieties, cold stored runners, fresh runners, marketable yield, average fruit weight

INTRODUCTION

Strawberry cultivation has been recorded locally since 1915 (Anon 1915) but commercial production took off as from 1961 with the introduction of various varieties from Kenya, France, South Africa and Australia (Anon 1961). Three main varieties namely Tioga, Tiobelle, Sequoia are being cultivated locally in the humid and super-humid areas of Mauritius, with a peak between October and November (Anon 1996). The variety Marquise that was introduced in 1994 has also been adopted by growers (Anon 2001). Import of fresh strawberry fruits has been 20 to 41 tonnes yearly during the last 5 years, as local production cannot meet the demand (Anon, 2002). The crop is seasonal and fruits are not available during the months of January to July. It is a luxury fruit crop and fetches high price compared to other fruits available locally. Some of the constraints at producer level include seasonality of production, limited varieties and pests and diseases (Anon 1996). Hence research was oriented towards screening high yielding varieties, extending the production season and diversifying the germplasm. This experiment was conducted for screening of 14 varieties namely Eros (British origin), Agathe, Camarosa, Diamante, Honeoye and Oso Grande (American origin) and Anabelle, Angelina, Anthea, Cigaline, Cijosée, Ciloe, Cirano and Cireine (French origin).

MATERIALS AND METHODS

The first trial consisted of evaluation of 14 varieties namely Agathe, Anabelle, Angelina, Anthea Camarosa, Cigaline, Cijosée, Ciloe, Cirano, Cireine, Diamante, Eros, Honeoye and Oso Grande during the period of April 2000 to January 2001. The 14 varieties were imported from France and planting materials were cold stored runners. After evaluation of the 14 varieties, four varieties namely Agathe, Cijosée, Diamante and Oso Grande were retained for further evaluation. The 4 selected varieties were tested from May 2001 to January 2002 with two locally cultivated varieties as control (Sequoia and Marquise) and using fresh runners.
Both trials were conducted at Wooton Crop Research Station using a randomised complete block design with 3 replicates. The plot size used was 90cm x 300 cm (2.7m²) with 30 plants. Plantation was conducted under high tunnel with transparent plastic raised over a metal framework measuring 4.5m wide, 2.1m high and 23m long. Mulching was effected using black plastic and irrigation was provided using drip system. Harvest of 3/4 to full ripe fruits was performed three times per week, early morning in shallow plastic punnets. All necessary precautions to avoid damage of fruits were taken.

The parameters observed were:

- Canopy diameter and plant height of 10 plants in 3 replicates taken at 4 months after transplanting.
- Marketable yield per plot
- Total number and marketable number of fruits
- Total soluble solids
- Fruit firmness
- Date of harvest
- Keeping quality
- Ability to produce runners

Fruits free from disease, insect damage, cracks and weighing at least 3g were considered as marketable. Fruits heavier than 15 g were graded as large, 6 to 15g as medium and 3 to 6g as small. Brix was measured in the month of November using a refractometer and fruit firmness was measured with a penetrometer having an 8 mm diameter probe. Mid harvest period was determined as the time to 50% production. Keeping quality was assessed on an arbitrary quality index scale developed in relation to fruit glossiness, firmness, disease incidence and the overall appearance after storage of marketable fruits in perforated plastic punnets at 80 – 95% RH, for 4 days at 5°C or 7 days at 2°C. A rating used as quality index was given as follows: 1-excellent, 2-good, 3-fair, 4-poor, 5-very poor.

The number of runners produced in April 2001 by the mother plants was counted and varieties producing a minimum of 3 runners/plant were considered as good producer of planting material. Disease occurrence was noted on each variety. The status of mite, the main pest recorded, was monitored using six leaves randomly in 3 replicates, and assessing once weekly for mite abundance with a 10x lens. Recommended acaricide application was performed when an average of 10 mites per leaf was observed.

RESULTS AND DISCUSSION

Evaluation using cold stored runners – Year 1 Trial

Plant development

All varieties showed vigorous growth when planted in the first year using cold stored runners, with a canopy height of 15 – 30cm and spread of 25 - 40cm. The mean height was least in Anabelle, Angelina, Cigaline, Cijosée, Ciloe, Cireine, Diamante, Eros, Honeoye (15 – 20cm) followed by Agathe, Anthea, Camarosa, Oso Grande (21 – 25cm) and greatest in Cirano (26 – 30cm). The least canopy diameter was recorded in Cijosée (25 – 30cm), followed by Anabelle, Angelina, Ciloe, Camarosa, Cirano, Eros, Honeoye (31 – 35cm) and highest in Agathe, Anthea, Cigaline, Cireine, Diamante, Oso Grande (36 – 40cm).

Yield and fruit grade

The varieties Agathe, Cirano and Anabelle performed best with marketable yields 488 – 547g / plant (Table1). Cijosée, Oso Grande, Camarosa, Anthea, Cigaline, Diamante and Angelina were the next best (205 - 418g/plant). Yield of Honeoye, Cireine, Eros and Ciloe were lowest and did not exceed 200g/plant. Agathe, Cirano, Anabelle and Cijosée also had high fruit set (60-84 fruit/plant) and highest proportion of marketable fruit (82 - 84%).

Diamante had the highest average marketable fruit weight and proportion of large size fruits followed by Oso Grande and Camarosa and these varieties also had less than 10% of small fruits. Angelina was
not considered promising because of the very high proportion (63%) of small fruits, an undesirable characteristic for the fresh market, and the negligible amount of large fruits (3%).

**Table 1** Average Yield, Weight and Grade of fruits

<table>
<thead>
<tr>
<th>Variety</th>
<th>Marketable yield /plant</th>
<th>Fruit set number %</th>
<th>Average fruit weight g</th>
<th>Grading %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agathe</td>
<td>547 a</td>
<td>84</td>
<td>71 ab</td>
<td>9.1 de</td>
</tr>
<tr>
<td>Cirano</td>
<td>498 ab</td>
<td>83</td>
<td>84 a</td>
<td>7.1 g</td>
</tr>
<tr>
<td>Anabelle</td>
<td>488 abc</td>
<td>82</td>
<td>64 bc</td>
<td>9.3 d</td>
</tr>
<tr>
<td>Cijosée</td>
<td>418 bcd</td>
<td>83</td>
<td>60 bcd</td>
<td>8.2 ef</td>
</tr>
<tr>
<td>Oso Grande</td>
<td>318 de</td>
<td>69</td>
<td>39 g</td>
<td>12.0 g</td>
</tr>
<tr>
<td>Camarosa</td>
<td>305 ef</td>
<td>68</td>
<td>41 efg</td>
<td>10.3 c</td>
</tr>
<tr>
<td>Anthea</td>
<td>282 fgh</td>
<td>58</td>
<td>63 bcd</td>
<td>7.7 fg</td>
</tr>
<tr>
<td>Cigaline</td>
<td>281 ef g</td>
<td>68</td>
<td>54 bcd</td>
<td>7.6 fg</td>
</tr>
<tr>
<td>Diamante</td>
<td>248 ef g</td>
<td>59</td>
<td>31 g</td>
<td>13.8 a</td>
</tr>
<tr>
<td>Angelina</td>
<td>205 fgh</td>
<td>65</td>
<td>58 bcd</td>
<td>5.5 h</td>
</tr>
<tr>
<td>SE±</td>
<td>32</td>
<td>-</td>
<td>3.99</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Fruit firmness**

Penetrometer readings showed that the varieties Anthea, Cireine and Honeoye were the least firm and was the main cause of bruising at picking and handling. Agathe, Anabelle, Cigaline and Eros were of intermediate firmness; Angelina, Cijosée, Cirano, Cilo and Oso Grande had higher fruit firmness whereas Camarosa and Diamante was the most firm.

**Earliness**

The time to 50% harvest was achieved in September and October for all the varieties; For Anabelle it was the last week of September, for Agathe, Anthea, Cijosée, Camarosa and Diamante the first week of October, for Angelina, Cigaline and Oso Grande the second week of October and finally for Cilo, Cireine, Eros and Honeoye the first week of November. Thus Anabelle, Agathe, Anthea, Cijosée, Camarosa and Diamante were the earliest varieties.

**Keeping quality**

Agathe, Oso Grande, Cijosée, Camarosa, Cirano and Anabelle, which had relatively good fruit firmness, were still of good quality after 4 days of storage whereas Cilo, Cireine, Angelina, Anthea and Cigaline became unmarketable, indicating poor keeping quality (Table2). Fruit of Diamante, Eros and Honeoye were not available in sufficient amount at testing for keeping quality.

**Ability to produce runners**

Out of the 14 varieties, Anabelle, Camarosa and Cirano were not good producers of runners and produced less than three runners per plant.
Table 2 Quality of fruits after 4 days of storage at 5°C

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Average Quality Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agathe</td>
<td>1.8</td>
</tr>
<tr>
<td>Oso Grande</td>
<td>1.9</td>
</tr>
<tr>
<td>Cijosee</td>
<td>2.1</td>
</tr>
<tr>
<td>Camarosa</td>
<td>2.3</td>
</tr>
<tr>
<td>Cirano</td>
<td>2.5</td>
</tr>
<tr>
<td>Anabelle</td>
<td>2.8</td>
</tr>
<tr>
<td>Ciloe</td>
<td>3.7</td>
</tr>
<tr>
<td>Cireine</td>
<td>3.8</td>
</tr>
<tr>
<td>Angelina</td>
<td>4.0</td>
</tr>
<tr>
<td>Anthea</td>
<td>4.7</td>
</tr>
<tr>
<td>Cigaline</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Evaluation Of Strawberry Varieties Using Fresh Runners – Year 2 Trial

Of the 14 varieties evaluated using cold stored runners, only Agathe, Anabelle, Camarosa, Cigaline Cijosée, Cirano, Diamante and Oso Grande had high overall marketable yield. However Anabelle, Camarosa and Cirano were poor producers of runners and hence were not further evaluated. The varieties Agathe, Cijosee, Diamante and Oso Grande were selected for further evaluation based on overall yield and quality (firmness, earliness, keeping quality, runner production) using fresh runners produced locally, with Sequoia and Marquise as control.

Plant development

The six varieties attained a canopy spread of 20 – 25cm and height of 9 – 13cm. There was no significant difference in the canopy spread among the varieties. However Agathe, Oso Grande and Sequoia produced significantly taller plants than Cijosée, Diamante and Marquise.

Yield

The variety Agathe outperformed all the other varieties again in the second year in terms of marketable yield of fruits when planted as fresh runners, with yield exceeding 500g/plant and it was more than twice that of the control (Table 3). Oso Grande was the second best. Yield of Cijosée, Diamante, Marquise and Sequoia did not differ significantly.

Table 3 Average Yield Parameters (plant basis)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Marketable yield</th>
<th>Total fruit set</th>
<th>Average fruit weight g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>% by number</td>
<td></td>
</tr>
<tr>
<td>Agathe</td>
<td>508 a</td>
<td>75</td>
<td>71 a</td>
</tr>
<tr>
<td>Oso Grande</td>
<td>360 b</td>
<td>76</td>
<td>41 bc</td>
</tr>
<tr>
<td>Diamante</td>
<td>290 bc</td>
<td>67</td>
<td>33 c</td>
</tr>
<tr>
<td>Cijosée</td>
<td>286 bc</td>
<td>71</td>
<td>52 ab</td>
</tr>
<tr>
<td>Marquise</td>
<td>222 c</td>
<td>65</td>
<td>49 b</td>
</tr>
<tr>
<td>Sequoia</td>
<td>191 c</td>
<td>68</td>
<td>39 bc</td>
</tr>
<tr>
<td>SE</td>
<td>53</td>
<td>-</td>
<td>6.4</td>
</tr>
</tbody>
</table>

SE ± Standard deviation. Common superscripts within columns represent no significant difference.
Fruit set was highest in Agathe and Cijosée. Diamante and Oso Grande again produced fruits with highest average fruit weight followed by Agathe. Marquise, Sequoia and Cijosée had the least average fruit weight (<7.3 g) and were not significantly different among themselves. 
The type of planting material influenced yields differently for each variety. The new varieties produced almost similar marketable yields with fresh runners (66-76%) but differed from cold stored runners by 7-15% in Agathe, Oso Grande and Diamante and by 32% in Cijosée. Fruit set and average fruit weight were similar with both types of planting material.

**Fruit Grade**

All varieties produced mainly medium size fruits. Agathe, Oso Grande and Diamante, which had the highest average fruit weight, also produced the highest proportion of large size fruits (20–40%) as shown in Figure 1. Marquise, Sequoia and Cijosée produced small fruits mainly (30–40%), with <10% of the large fruits. Varieties with high proportion of large and medium size fruits are expected to fetch better price in the fresh market than those with high proportion of small size fruits. Hence Agathe, Oso Grande and Diamante are expected to have good consumer demand.

![Figure 1](image_url)

In general, all the new varieties produced higher proportion of small size fruits with fresh runners (12-39%) than with cold stored ones (3-17%) as shown in Figure 2.

**Fruit Quality Parameters**

Brix was least in Diamante, Oso Grande and Sequoia (7ºB), higher in Agathe and Cijosée (8ºB) and highest in Marquise (9ºB). Fruits showing 7-10ºB indicate a desirable organolaptic characteristic of the strawberry variety (Roudelliac and Veschambre, 1987). Thus, all the varieties evaluated had the desired minimum brix.

Penetrometer readings showed that firmness was good in all varieties; Diamante was the most firm (0.8 kg / 8mm²) followed by Sequoia, Cijosée and Oso Grande (0.6 kg / 8mm²) and Marquise and Agathe were of intermediate firmness (0.4-0.5 kg / 8mm²)

**Earliness**

Harvest started in July, in the third week in Agathe, Cijosée, Diamante, Marquise and Oso Grande, and in the fourth week in Sequoia. In October, that is at least twelve weeks later, all varieties attained the time to 50% harvest. However, the new varieties were earlier than the control by one to two weeks.
Growing the new varieties would imply quicker revenue to the farmer, who can then also benefit from the higher market price in the early season. Oso Grande was the earliest (12 weeks), followed by Agathe, Cijosé and Diamante (12½-13 weeks), Sequoia (13 weeks) and Marquise (14 weeks).

**Keeping quality**

All varieties were of similar satisfactory quality not exceeding index 4 after the 7 days of storage at 2°C, with no significant difference among varieties (Figure 3).

**Pest and disease occurrence and susceptibility**

The main diseases recorded were botrytis and anthracnose on fruits of all varieties while powdery mildew was observed on the varieties Sequoia, Marquise and Agathe only. Moreover the mite (*Tetranychus* spp) was the major pest encountered. The number of mites per leaf among the six varieties evaluated did not differ significantly.

![Figure 2](image1)

**Figure 2** Fruit grades among cold stored runners

![Figure 3](image2)

**Figure 3** Quality index of fruits after 7 days of storage at 2°C
CONCLUSION

Under the conditions evaluated, the new varieties Agathe, Anabelle, Camarosa, Cijosée, Cirano, Diamante and Oso Grande performed well as cold-stored runners with high overall marketable yields. Angelina, Anthea, Cigaline, Ciloe and Cireine, Eros and Honeoye had poor overall marketable yields whereas Anabelle, Cumarosa and Cirano were poor producers of runners. Agathe, Cijosée, Diamante and Oso Grande were retained for further evaluation in the second year using fresh runners and with Marquise and Sequoia as control. In general, all the new varieties produced higher proportion of small size fruits with fresh runners than with cold stored ones, had similar average fruit weight but differed in marketable yields by 7-15% in Agathe, Oso Grande and Diamante and 32% in Cijosée.

Agathe outperformed the other varieties with respect to yield (508 g/plant) and fruit set (71 fruits/plant). Yield of Agathe was more than twice that of Marquise and Sequoia. Oso Grande was the next best variety with yield of 360g/plant whereas there was no significant difference among Diamante, Cijosée, Marquise and Sequoia (191-290g/plant). Moreover, Agathe, Diamante and Oso Grande produced the highest proportion of large fruits and had the highest average fruit weight. Marquise, Sequoia and Cijosée, on the other hand, had least average fruit weight and produced small fruits mainly and little large fruits. The six varieties had the minimum desirable brix and had good fruit firmness and good keeping quality. Agathe, Cijosée, Diamante and Oso Grande attained the time to 50% harvest earlier than the control by one to two weeks.

ACKNOWLEDGEMENTS

I wish to express my gratitude to the Director and Assistant Director (Crops) of AREU for their permission to publish this paper. I would also like to extend my thanks to Mr R Ramnauth, Mrs N Ramburn and Mr P Hanoomanjee for their useful criticism, as well as to all the staff of AREU concerned with the project.

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STATUS OF MUSHROOM PRODUCTION AND RESEARCH IN MAURITIUS

P Huzar Futty
Agricultural Research and Extension Unit

ABSTRACT

Mushrooms are cultivated for their nutritive and medicinal values. In Mauritius, they are highly appreciated for their taste and flavour and are consumed both in fresh and processed forms. In 2001, the annual value of mushroom imports (including fresh, preserved and dried produce) attained MUR 21 Millions while the annual local Pleurotus production is estimated at more than 15 tons for 2001. Due to their high market value, the fresh local produce fetched around Rs 100 – 120 / kg. From the trends of past years, the demand and consumption of mushrooms is expected to continue increasing. Of the several varieties introduced and evaluated in the past, Pleurotus was identified as being both economically viable and suited for local cultivation. The strain is cultivated on pasteurized bagasse substrate. The adoption of the plastic bag method of cultivation has encouraged numerous backyard growers to try mushroom production. The number of regular growers now amounts to around 35. The Agricultural Research and Extension Unit (AREU) provides regular assistance to small and large scale growers interested in mushroom production. Growers can purchase their fruiting bags and spawn from the Mushroom Unit of AREU. In the recent years, AREU has helped 3 entrepreneurs to start their own substrate preparation and production of fruiting bags. Research at AREU presently deals with improvement of existing cultural practices, identification of alternative substrates, improvement of mushroom strains for adaptability to the local agroclimatic conditions and diversification of production through evaluation of other mushrooms including Lentinula, Auricularia and Calocybe.

Keywords: mushroom, production, research, diversification, Pleurotus, Lentinula, Calocybe, Auricularia.

INTRODUCTION

Traditionally used as a delicacy, mushroom has been collected and consumed for more than 2000 years in Greece, China and Japan. Several mushroom species were also known for their medicinal properties. Mushrooms represent a small fraction of the Kingdom Eumycota and are termed “fleshy fungi”. They are non-photosynthetic and depend on other plant material (the substrate) for their food. Cultivated mushrooms are generally saprophytes that draw their nutrition from dead plant materials. People have long been interested in mushrooms for their nutritional and medicinal aspects. Nutritive value of mushrooms is attributed to their high content of essential amino acids, vitamins, minerals and low lipid content. The medicinal properties include, among others, prevention and alleviation of tumours, heart disease or viral infections. Mushrooms cultivation help manage problematic organic wastes since agricultural and food processing by-products can be used as cultivation media. After harvests, the spent substrate obtained is composted prior to application to the soil as organic amendments.

Of the several thousands of mushroom species known worldwide, only around 2 thousands are considered edible, of which about 20 are cultured commercially, with only 4 to 5 under industrial production (Chang S. T., 1990). The multimillion mushroom industry has increased from a world production of 1,802,487 Mt in 1991 to about 2,710,761 Mt in 2001 (FAO, 2002). International mushroom research is geared to meet the expectations of the increasing demand and consumption of mushrooms worldwide.

In Mauritius, mushrooms are well appreciated for their exquisite taste and flavor and are consumed both in the fresh and processed forms. Fresh mushrooms are in good demand locally and fetch a relatively high market price. Mushroom derived products such as beverages, medicinal tonics, various
cosmetics and pharmaceuticals (Chang, 1991) are also being more accepted on the Mauritian market in parallel with the trend for consumers to accept ‘bio’ products. Though mushroom cultivation has been attempted on and off for almost 40 – 50 years, the bulk intended for local consumption has to be imported. With the yearly imports reaching up to around MUR 21 millions, and the steady increase in consumption, there is a definite scope for Mauritius to increase its actual production till self-sufficiency is reached (import substitution) and eventually to attempt export to neighbouring countries.

Mushroom is mostly imported fresh / chilled, canned, preserved in vinegar or acetic acid or air dried (whole, sliced, broken, powder). The most ‘popularly’ consumed mushroom in Mauritius is the canned Button mushroom (Agaricus sp.), chiefly imported from China, Netherlands, Thailand and France. Around 26 tonnes are imported fresh from countries including South Africa and Australia.

At the end of 1970s, the Ministry of Agriculture (MoA) conceptualised a mushroom project with the aim to:

1) identify and evaluate mushroom varieties suitable for local production, and
2) promote its cultivation in Mauritius.

A cultivation package for Pleurotus (Oyster mushroom) cultivation was successfully developed and adopted locally. AREU is presently responsible for promoting mushroom cultivation and carrying out mushroom research to ensure a need oriented work plan.

**Mushroom demand**

The increasing values of mushroom imports for the last five years (Table 1) give an appreciable idea of the high demand for mushrooms. This increase in mushroom consumption may be associated to the increasing number of tourists yearly, the higher standards of living with increased purchasing power of Mauritians and their changing food habits (incorporation of Chinese cuisine in the Mauritian culinary habits, vegetarianism, etc.).

<table>
<thead>
<tr>
<th>QUANTITY Kg</th>
<th>VALUE Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mushrooms, fresh or chilled</td>
<td>15,190</td>
</tr>
<tr>
<td>Dried mushrooms and truffles, whole, cut, sliced, broken, powder</td>
<td>49,590</td>
</tr>
<tr>
<td>Mushrooms, prepared or preserved otherwise than by vinegar or acetic acid</td>
<td>425,530</td>
</tr>
</tbody>
</table>

Source: Biometry Unit (AREU)

Due to lack of information, exact market mushroom preferences cannot be determined. However, it has been observed that Button mushroom is the most popular in local cuisine, followed by Specialty mushrooms (e.g. Shiitake and Wood Ear mushroom) and truffles. The demand for fresh mushrooms is mainly from hotels and restaurants. The fresh produce is displayed in cold cabinets of supermarkets making it readily available to consumers.

The actual price of the locally produced mushroom is around Rs 100-120 / kg. Good quality mushrooms may fetch prices as high as Rs 150-175 / kg in the hotel industry. A developing market for the processed produce is also gathering momentum. New products like mushroom pickles are gaining in popularity. A 200g jar of Pleurotus pickle in spices sells at around Rs 65-70 and in brine at about Rs 75.
The demand for fresh mushrooms is expected to increase steadily in the coming years. On the basis of the percentage import value of the last five years, a trend towards an increase in fresh mushroom import is noted. Dried and preserved mushroom imports are relatively stable (Table 2).

Table 2  Representative percentage values of different forms of mushrooms imported yearly

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mushrooms, fresh or chilled</td>
<td>3.7</td>
<td>5.9</td>
<td>11.3</td>
<td>9.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Dried mushrooms and truffles</td>
<td>16.5</td>
<td>13.3</td>
<td>17.2</td>
<td>15.0</td>
<td>13.4</td>
</tr>
<tr>
<td>Mushrooms prepared or preserved</td>
<td>79.8</td>
<td>80.8</td>
<td>71.5</td>
<td>75.9</td>
<td>75.7</td>
</tr>
</tbody>
</table>

The market for processed mushroom products like pickles in spices, chips and snacks and other such related value added produce is likewise expected to increase.

Local Mushroom Production

The mushroom variety found to be most suitable for local cultivation is the *Pleurotus* (Oyster mushroom). This conclusion was reached after a series of trials carried out on other varieties proved not to be economically viable.

In 1982, the CATT (Chinese Agricultural Technical Team) introduced the *Pleurotus* mushroom to Mauritius. The latter is a vigorously growing high yielding strain, well adapted on locally available substrate and relatively well suited to the local agro-climate. The most promising species is the *Pleurotus sajor-caju*.

Since then the estimated production of fresh *Pleurotus* mushrooms in Mauritius has steadily increased from 4800 kg in 1993 to around 12,000 kg in 1996 and over 15,000 kg in 2001. Mushroom production estimates has been calculated based on the production at the Mushroom Unit of AREU as well as the quantity of fruiting bags and spawn bags put on sale.

The production of 15 tonnes of fresh mushrooms is insufficient compared to the actual requirement of around 41 tonnes. Thus there is a definite potential for an increase in fresh mushroom production.

Mushroom growers of Mauritius

Several attempts were made down the last 40 to 50 years by individual mushroom amateurs to grow ‘Champignon de Paris’ (*Agaricus bisporus*). Due to improper substrate and methodology, these attempts were mostly unsuccessful.

Trials on *Agaricus bisporus* (Lange) undertaken by the University of Mauritius (Peerally, 1978) obtained some success but were later abandoned. A little more than a decade ago a large-scale mushroom farm for *Agaricus bisporus* cultivation was set up by a private enterprise. This foray into *Agaricus* production was also abandoned. Reasons put forth in this case were:

- high running costs for *Agaricus* production
- sophisticated production technology
- production of button mushrooms being uneconomical for our conditions

Following the introduction of *Pleurotus* in 1982 by the CATT / MoA and its adoption locally, several small-scale growers started production of the oyster mushroom. They initially started with the bagasse – block production technology until in the mid 1990s they adopted the improved method of production referred to as plastic bag method of cultivation. In this method, the substrate is filled into plastic bags, pasteurized and then inoculated. After the incubation period, the colonized bags are allowed to fructify.

These fruiting bags, which are easier to handle and transport, permit a greater number of small-scale growers to start their mushroom cultivation. Both backyard and commercial mushroom growers have adopted this method of cultivation. It should be pointed out that backyard individual growers produce mushrooms for their own consumption while commercial growers market their produce.
During the last 3 years, increasing numbers of entrepreneurs have successfully contacted AREU for technical advice, visits and training prior to starting their mushroom enterprise. Around a dozen of these trained women entrepreneurs have undertaken mushroom cultivation for additional revenue.

The actual number of individual growers cultivating only a few bags is very large. An approximate number based on the number of visits to the Mushroom Unit of AREU is around 500 per year. The number of regular growers procuring themselves with fruiting bags from AREU or from local fruiting bag producers is around 35.

The only semi-industrial production of *Pleurotus* mushrooms was started 14 years back (in 1988) at Mon Désert Alma (Stellio P. 1991). Their aim of producing 500 kg of *Pleurotus* monthly was almost attained after 3 years. The ultimate objective of their 3-phase mushroom production project was to produce 3 tonnes of *Pleurotus* monthly. However, this mushroom project was inexplicably dropped after a few years.

It was not until around 1999 that, with the help of AREU, three growers set up their own production facilities. These growers have mushroom farms that are fully equipped with a pasteurizer, inoculation area, incubation and fructification rooms and the proper packaging equipment. They are currently operating successfully and besides the sale of fresh mushrooms, growers have started marketing the fruiting bags that they produce. Another grower has just launched his own production of fruiting bags and a few others are expected to follow. An increase in growers’ preference to go into fruiting bag production is shown by the number of spawn sold at AREU (Figure 1).

**Figure 1** Spawn sale at AREU

The AREU has assisted representatives from foreign countries to start mushroom production. Countries having benefited from AREU’s work are Rodrigues, Madagascar, Kenya, Réunion and Seychelles.

**Constraints of mushroom production in Mauritius**

**Market acceptability**

Mauritian consumers have a marked preference for the Button mushroom that is imported canned and they thus have to be further familiarised with other mushrooms which can be cultivated locally like fresh *Pleurotus, Auricularia, Lentinula*, etc.
Short shelf life of fresh Produce

Fresh *Pleurotus* mushrooms have a short shelf life at ambient conditions and hence requires a cold chain for its marketing. An increase in local production will entail the development of different methods to extend shelf life and to preserve the mushrooms.

Marketing

Fresh mushroom production needs to be developed to its maximum extent. Aggressive marketing of the produce will allow growers to achieve full market penetration and exploit all potential niche markets. This will permit a minimisation of imports, future self-sufficiency in mushroom requirements and also finally to exploit export markets (to neighbouring islands and countries).

The marketing strategy

The strategy to be adopted while marketing the locally cultivated mushrooms should be centered on the advantages of the fresh produce as opposed to the imported produce (processed form). Sensitization of the public as to the benefits of mushroom through publicity by the media and recipe demonstrations will help promote local consumption. Proper sensitization will help consumers to opt for the healthier fresh product with a better taste and quality as opposed to the imported canned and preserved ones. They may even be encouraged to pay a higher price for the fresh mushroom.

Unwillingness to start own production

Most of the small-scale growers are dependent on AREU for their supply of fruiting bags. The latter being quite easily and cheaply available from AREU, with no labour and other input requirements, few growers are interested to invest money and energy in mushroom production. This has given rise to a limiting factor that is the chief reason mushroom production has not increased drastically in Mauritius. To solve this problem, AREU is actively encouraging growers to start their own production.

Substrate availability

Among the range of agro wastes available locally, sugar cane bagasse was found to be the most suitable substrate for *Pleurotus*. However, recently, bagasse is being increasingly used for energy production by factories. This has lead to an increase in price and a decrease in bagasse availability. Thus growers will have increasing problems in obtaining this substrate.

Mushroom Research in Mauritius – The Status

Research on mushroom has been focalized on several themes and aspects. In the past, evaluation of formulation for substrates and cultural practices were attempted in order to develop cultivation packages for mushroom varieties assessed. Trials on *Agaricus* were relatively successful contrary to those on *Volvariella* (Paddy straw mushroom) where erratic yield and unavailability of paddy straw acted as deterrents.

The present status of research also revolves around these important factors so as to improve existing practices as well as a series of new themes. Research on mushrooms carried out by AREU is aimed at:

Identification of suitable substrate for cultivation

Since as early as the 1970's bagasse, the main substrate for local mushroom cultivation, was predicted to become scarce in the coming years (Patourau, 1978). This is due to the fact that bagasse is being employed as a major source of fuel for sugarcane factory. In this context, trials are underway to find an alternative substrate for the production of the mushroom. From the trials carried out at AREU, preliminary results have indicated the suitability of banana leaves, certain grasses and coconut coir as substrate for *Pleurotus*. 

Improvement of cultural practices

Pleurotus cultivation practices are being reviewed. Despite the adoption of the plastic bag method of cultivation on racks, attempts are being made to find simpler cultivation methods that may give advantages such as ease of production, substrate filling, decreased costs and higher productivity. Among those practices being evaluated is the cylinder system of cultivation. Other aspects like the evaluation of different methods of spawning e.g. bulk, layered and surface spawning are also underway.

Diversification of mushroom production

Another major focus of research on mushrooms in Mauritius is that of the diversification of mushroom production.

Lentinula edodes (Shiitake)

The Lentinula edodes (Lentinus edodes) has been traditionally grown on wood logs in Asia since more than 1,000 years. It is the fourth largest mushroom cultivated in the world (Sharma SS. 1995). Appreciated for its unique taste and flavour, shiitake is important in the medicinal world due to its content of ‘Lentinan’, which reduces plasma-cholesterol and has antitumour effect.

The attempts made to grow Lentinula at the Mushroom Unit have given promising results with highly successful fructifications. Trials on the ideal substrate for Lentinula cultivation have indicated the suitability of sawdust as substrate. However, maximum yield is still obtained on a maize grain medium. Cultural practices of Lentinula are also being investigated and have clarified the conditions required for incubation and induction of fruits by immersion or cold shock. The Chinese method of soil cultivation of Lentinula is also being investigated.

Calocybe indica (White Summer mushroom)

A new strain Calocybe indica was introduced in year 2001. Calocybe is a high temperature mushroom that can grow at temperature ranges of 25º - 35º C. The strain was successfully subcultured. A bagasse based substrate allowed very poor growth of the mushroom mycelium. Further work is underway to identify the ideal substrate for the mushroom. During the observation trial performed at the Mushroom Laboratory of AREU a few fruit bodies of Calocybe were successfully obtained.

Auricularia auricula (the Wood Ear or Black Ear mushroom)

A new strain of Auricularia auricula was introduced in year 2001. Auricularia (order Tremallales) is characterized by gelatinous fruit bodies. It has long been believed to cure sore throat, anaemia and digestive disorders on regular consumption. The Wood Ear mushroom is imported and available in the dried form on the local market. It is quite popular in Chinese cuisine. During year 2002, preliminary attempts on producing Auricularia mushroom have been very promising. Further work needs to be carried out in order to establish the cultural practices and confirm the mushroom’s potential for our local conditions. The fruit bodies of Auricularia were allowed to develop on a bagasse-based substrate that was previously inoculated with pure spawn of Auricularia.

Improvement of strains

Research performed in the field of Pleurotus cultivation chiefly deals with improvement of strains for adaptability to high temperatures and dry conditions. The trials carried out in this context aims at characterizing and improving available strains of Pleurotus so as to have the most promising strain under cultivation locally. It also entails regular evaluation of potential strains prior to adoption for cultivation.

Future prospects for the industry

It is expected in the future to have several other mushrooms being grown in Mauritius. This will include edible species such as Lentinula, Auricularia, Calocybe and ultimately medicinal species like Ganoderma. These high quality fresh mushrooms would chiefly be aimed for local and export
markets. It is probable that very little of Mauritian mushrooms will be destined for canning as it may not be possible to compete with cheap canned imports from countries such as Taiwan. Processed forms of mushrooms including pickles etc, would be exploited for the local market. The scope for exportation of fresh mushrooms is also not to be neglected.

The production technology would need to be extended to Rodrigues. Local growers are expected to increase in number and activity and adopt contract growing, allowing a greater production level. This will in turn promote the achievement of a second phase in mushroom cultivation whereby one or more growers would set up their own spawn production facility.

CONCLUSION

Mauritius imports a considerable quantity of mushrooms yearly and the local production is insufficient to meet the actual demand. A potential, thus exist for an increase in our local production. The collaborative working of mushroom growers and marketing personnel will allow the mushroom industry to expand according to the needs of consumers.

AREU, presently responsible for extension work on mushrooms, has assisted several growers to start mushroom cultivation. Most of these growers utilized fruiting bags obtained from the mushroom Unit of AREU. Recently, some entrepreneurs have successfully set up their own production facilities. It is incumbent on the Extension Department to further encourage growers to start their own substrate production and ultimately to promote spawn production among large-scale producers.

Market acceptability, short shelf life of fresh mushrooms, marketing and a general unwillingness of growers to launch into independent production are constraints that hinder the increase of local mushroom production.

Research underway at AREU aims at eliminating some of these constraints. Themes being investigated in order to improve the future prospects of the Mushroom Industry are improvement of cultural practices, identification of suitable substrate, diversification of production and improvement of strains.

ACKNOWLEDGEMENTS

To the Director of AREU, Assistant Director (Crop), the Officer in Charge (Vegetables and Ornamentals Division) for allowing me the opportunity to present this paper and for reviewing the manuscript.

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PINEAPPLE: EFFECT OF DIFFERENT FLOWER INDUCTION TIMES ON CROP CYCLE LENGTH AND YIELD

Riaz Ahmad Bhugaloo

Agricultural Research and Extension Unit

ABSTRACT

Studies were conducted to evaluate the effect of different flower induction treatment times on crop cycle length and yield of pineapple (cv. Queen Victoria) on three sites: Camp de Masque Pavé, Congomah / Camp La Boue and Ville Noire / Beau Vallon. Suckers of size 250 to 300 g were used as planting material. Flower induction was effected 5 months, 6 months, 7 months, 8 months or 9 months after planting. Data on number of leaves, length of crop cycle, total yield and mean fruit weight were collected. Results showed that the number of leaves increased significantly with an increase in flower induction treatment time. The length of crop cycle was around 75 days longer when flower induction treatment was effected in winter. The total yield and mean fruit weight were higher at Ville Noire / Beau Vallon compared to the other two sites. Flower induction treatment time and the regions significantly (P<0.05) influenced the weight of fruits at harvest.

Keywords: Ananas comosus, crop cycle, fruit, pineapple, sucker, yield.

INTRODUCTION

Among plants cultivated on a commercial scale, pineapple, Ananas comosus (L) Merr., responds readily to artificially induced flowering. This characteristic of pineapple plays a highly significant role in production planning. Additional benefit is obtained when artificial flower induction results in fruits complying with marketing standards. This implies that the exact stage of growth at which flower induction is to be carried out must be determined with respect to the desired type of fruit. Therefore, proper planning of planting dates combined with appropriate flower induction times is essential. The objective of this trial was to determine in the three main zones of pineapple production in Mauritius, the optimum planting date and flower induction time in order to target market requirements.

MATERIALS AND METHODS

The experiment was carried out with cv. Queen Victoria at three sites: Ville Noire (altitude: 20m; subhumid region), / Camp La Boue (altitude: 131m; subhumid region), and Camp de Masque Pavé (altitude: 165m; humid region). The treatments used were five flower induction times: 5, 6, 7, 8, and 9 months after planting. Plantations were effected on a monthly basis for three years using suckers of weight 250 to 300 g: starting January 1998 at Ville Noire, February 1998 at Congomah / Camp La Boue and March 1998 at Camp de Masque Pavé. The design used was a randomised complete block with two replicates.

Each experimental plot at the three sites contained 200 plants. At Ville Noire, the plot size was 450 m², with four rows of plants spaced at 20 cm between rows and 20 cm within rows (density of 133 000 plants ha⁻¹). At Congomah / Camp La Boue and Camp de Masque Pavé, the plot size was 603 m² with three rows of plants spaced at 30 cm between rows and 20 cm within rows (density 100 000 plants ha⁻¹). At Ville Noire plantations were effected using plastic mulch while at the other two sites, no mulch was used. Planting materials for all sites were taken from the nursery of Tropical Bliss Ltd., at Ville Noire.
Fertilisers were foliar applied in seven split doses of 1.5 g urea and 2.15 g sulphate of potash per plant per application using the knapsack sprayer. At Ville Noire, the first two applications were applied in solid form before placing the plastic mulch and the five remaining doses were foliar applied. Flower induction treatments were performed 15 days after the last fertilisation using Ethrel (Ethephon) at the rate of 1500 ppm, sprayed on the whole foliage with a knapsack sprayer. The cultural practices were maintained as for usual commercial crops. Fruits were harvested at 50% colour development and data on number of leaves at flower induction treatment time, length of crop cycle, fruit weight, and yield were recorded.

RESULTS AND DISCUSSION

Number of leaves

The number of leaves counted at flower induction time, showed that at the three sites the number of leaves was maximal 9 months after planting (Table 1). It is obvious that the number of leaves increases with the age of plants. The number of leaves at Ville Noire / Beau Vallon was consistently higher than at the other two sites (Figure 1). This is due to the positive influence of plastic mulch and higher temperature on growth rate at Ville Noire / Beau Vallon (Py et al., 1987).

<table>
<thead>
<tr>
<th>FIT (Months)</th>
<th>Camp de Masque Pavé</th>
<th>Congomah / Camp la Boue</th>
<th>Ville Noire / Beau Vallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>23.0 c 19.5 d 19.3 d 22.3 e 19.6 d 19.9 e 25.8 e 21.3 d 20.8 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>23.5 c 20.8 cd 21.7 c 23.9 d 21.0 cd 22.8 d 28.8 d 23.9 d 25.3 c</td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td>26.5 b 22.6 bc 23.5 b 25.5 c 23.3 bc 24.7 c 31.5 c 26.8 b 27.8 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>28.6 a 24.1 b 26.1 a 27.3 b 24.6 ab 26.9 b 33.3 b 29.0 ab 28.0 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>29.5 a 26.7 a 26.7 a 28.2 a 26.2 a 28.9 a 35.2 a 31.6 a 31.1 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S.E. ± 0.28 0.96 0.29 0.28 0.96 0.29 0.28 0.96 0.29

P = 0.05

Fruit weight

The increase in fruit weight with increasing flower induction time was not significant at Camp de Masque Pavé in 1999. However, there was a significant increase in fruit weight as the flower induction time was increased up to 9 months after planting at Camp de Masque Pavé in 1998 and 2000. Results were consistent at Congomah / Camp La Boue and Ville Noire / Beau Vallon for all three years (Table 2). The mean fruit weight depends on the level of development and on the stage of growth of the plant at flower induction, which in turn determines the number of fruitlets and the weight of fruit (Py et al., 1987). The average fruit weight at Ville Noire / Beau Vallon was around 42% heavier than that at the other 2 sites (Figure 2). The larger fruits resulted from the positive influence of plastic mulch on growth rate through moisture conservation and increased soil temperature (Ekern, 1967).
Figure 1 The number of leaves at different flower induction times (1998 to 2000)
Table 2 Effect of flower induction times on fruit weight (1999 - 2001)

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>5</td>
<td>426</td>
<td>c</td>
<td>298</td>
<td>c</td>
<td>230</td>
<td>c</td>
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<td>c</td>
<td>249</td>
<td>c</td>
<td>455</td>
<td>b</td>
<td>386</td>
</tr>
<tr>
<td>7</td>
<td>463</td>
<td>abc</td>
<td>315</td>
<td>270</td>
<td>bc</td>
<td>501</td>
<td>ab</td>
<td>399</td>
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<tr>
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<td>316</td>
<td>305</td>
<td>ab</td>
<td>536</td>
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<td>413</td>
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<td>a</td>
<td>317</td>
<td>348</td>
<td>a</td>
<td>559</td>
<td>a</td>
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<td>a</td>
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<td>S.E. ±</td>
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<td>8</td>
<td>22</td>
<td>23</td>
<td>8</td>
<td>22</td>
<td>23</td>
<td>8</td>
<td>22</td>
</tr>
</tbody>
</table>

S.E. ± - Standard error
N.S. - Not significant
* - Means are significantly different at 5% level of significance
Means accompanied by different letters in each column are significantly different at 5% level of significance

Table 3 Fruit weight obtained with respect to flower induction times (1999 - 2001)

<table>
<thead>
<tr>
<th>Sites</th>
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<th>Year 2000</th>
<th>Year 2001</th>
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<td>&lt; 450</td>
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<tr>
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<td>450 – 600</td>
<td>g</td>
<td>&lt; 450</td>
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<tr>
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<td>5, 6, 7, 8, 9</td>
<td>450 – 650</td>
<td>g</td>
<td>450 – 650</td>
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<tr>
<td>Camp de Masque Pavé</td>
<td>7, 8, 9</td>
<td>450 – 550</td>
<td>g</td>
<td>&lt; 450</td>
</tr>
<tr>
<td>Congomah / Camp La Boue</td>
<td>7, 8, 9</td>
<td>450 – 600</td>
<td>g</td>
<td>&lt; 450</td>
</tr>
<tr>
<td>Ville Noire / Beau Vallon</td>
<td>7, 8, 9</td>
<td>650 – 750</td>
<td>g</td>
<td>450 – 650</td>
</tr>
</tbody>
</table>

At Camp de Masque Pavé, small fruits of size less than 450 g were produced with all flower induction treatment time over the three years, qualifying only for a niche market of baby pines. However, we obtained fruits of 450 to 550 g with a flower induction time of 7 to 9 months after planting in the year 1999.

At Congomah / Camp La Boue, fruits of size 450 to 600 g were produced for all flower induction times in the year 1999, and when induction was effected 7 to 9 months after planting in the year 2001 (Table 3). However, fruits of size less than 450 g were obtained for all flower induction treatment times in 2000, and when induction was effected less than 7 months after planting in the year 2001.

At Ville Noire / Beau Vallon, flower induction can start as from 5 months after planting to produce fruits of size 450 to 650 g in 2000 and 2001. However, in 1999, fruits of size 450 to 650 g were produced with a flower induction time of less than 7 months after planting while flower induction effected 7 to 9 months after planting produced fruits weighing 650 to 750 g

Yield

The increase in yield with increasing flower induction time was not significant at Camp de Masque Pavé in 2000. However, the yield increased significantly with an increase in flower induction time at Camp de Masque Pavé in 1999 and 2001. Similar effect was observed at Congomah / Camp La Boue and Ville Noire / Beau Vallon for all three years (Table 4).

This is obvious, since size of plants increased with increase in flower induction time. Again higher number of leaves contributes to produce bigger fruits and higher yields. The weight of the plant, leaf mass and the weight of D-leaf at flower induction are all directly linked with the weight of the fruit (Py et al. 1962). It is to be noted, that the yields at Ville Noire / Beau Vallon were higher than at the other two sites, due to the fact of a higher planting density (4 rows per bed at Ville Noire compared to 3 rows at the other two sites) and larger fruits at harvest. Das et al. in the year 2000 obtained a relatively higher yield of fruits by increasing the plant density.

Figure 2 Effect of flower induction times on fruit weight (1999 - 2001)

- Camp de Masque Pavé
- Congomah / Camp la Boue
- Ville Noire / Beau Vallon
Table 4: Effect of flower induction times on yield (1999 - 2001)

<table>
<thead>
<tr>
<th>FIT (Months)</th>
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<th>Congomah / Camp la Boue</th>
<th>Ville Noire / Beau Vallon</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>42.6 c</td>
<td>29.8</td>
<td>23.0</td>
</tr>
<tr>
<td>6</td>
<td>44.0 c</td>
<td>30.3</td>
<td>24.9</td>
</tr>
<tr>
<td>7</td>
<td>46.3 abc</td>
<td>31.5</td>
<td>27.0</td>
</tr>
<tr>
<td>8</td>
<td>50.9 abc</td>
<td>31.6</td>
<td>30.6</td>
</tr>
<tr>
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<td>52.3 a</td>
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</tr>
<tr>
<td>S.E. ±</td>
<td>2.60</td>
<td>0.81</td>
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</tr>
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</table>

N.S. - Not significant
S.E. ± - Standard error
* - Means are significantly different at 5% level of significance
Mean accompanied by different letters in each column are significantly different at 5% level of significance

Crop cycle length

The interval between flower induction time and harvest varied between 135 to 208 days at Congomah / Camp La Boue, 138 to 225 days at Camp de Masque Pavé and 114 to 207 days at Ville Noire (Table 5). Figure 3 illustrates the highest and lowest values of the interval between flower induction time and harvest respectively. At all three sites, the average interval was lengthened by 75 days for floral induction carried out during winter. This increase was due to the low temperatures prevailing during winter (average minimum of 15°C), thus delaying fruit development. On the other hand, fruit development was hastened in Summer due to accelerated growth (Bartholomew and Malézieux, 1994).

Figure 3: Interval between FIT and harvest Highest and Lowest values (1998 to 2000)
### Table 5 Crop cycle (Highest and lowest values – 1999 to 2001)

<table>
<thead>
<tr>
<th></th>
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<td>Hrvst</td>
<td>FIT</td>
<td>Hrvst</td>
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<td>Hrvst</td>
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<tr>
<td>CDMP</td>
<td>Jul-99</td>
<td>192</td>
<td>May-00</td>
<td>225</td>
<td>Jul-01</td>
<td>206</td>
</tr>
<tr>
<td>CGM / CLB</td>
<td>May-99</td>
<td>193</td>
<td>May-00</td>
<td>208</td>
<td>May-01</td>
<td>201</td>
</tr>
<tr>
<td>VN / BV</td>
<td>May-98</td>
<td>207</td>
<td>Jul-00</td>
<td>187</td>
<td>Apr-01</td>
<td>183</td>
</tr>
</tbody>
</table>

FIT: Flower induction treatment

### CONCLUSION

The length of crop cycle was increased by 75 days for floral induction carried out during winter at all three sites. This increase was due to the low temperatures prevailing during winter (average minimum of 15°C), thus delaying fruit development. On the other hand, growth was accelerated during summer. The number of leaves at flower induction time, total yield and mean fruit weight were higher at Ville Noire / Beau Vallon compared to the other two sites. The region and the flower induction times influence the weight of fruits at harvest. At Camp de Masque Pavé, small fruits of size less than 450 g were produced with all flower induction treatment times qualifying only for a niche market of baby pines. At Congomah / Camp La Boue, similar fruits were produced when induction was effected less than 7 months after planting (Table 3). However, fruits of size 450 to 600 g were obtained for flower induction treatment times of 7 to 9 months after planting. At Ville Noire / Beau Vallon, flower induction can start as from 5 months after planting to produce fruits of size 450 to 650 g. The number of leaves, which increases significantly with flower induction time and better growth rate, contribute in producing higher yields and fruits of bigger size. The optimum planting date is in the beginning of the summer season and the most appropriate flower induction time depends on climatic conditions prevailing, stage of growth of plant and the size of fruits required.

### ACKNOWLEDGEMENTS

I am infinitely grateful to X. D’Unienville, S. Desvaux, E Desjardhin and A. Fay’dherbe of Tropical Bliss Ltd. for their assistance. The facilities obtained from P. Dossieah and N. Kooblall of Montagne Longue, D. Fowdar, R. Jeewon, S. Proag, and A. Purmessur of Camp de Masque Pavé are hereby acknowledged. I also wish to convey my gratitude to R. Ramnauth for his advice on the experimental methodology and analysis of the data. Last but not the least, I extend my sincere thanks to the extension staff.

### REFERENCES


COMPARATIVE PERFORMANCE OF FOUR SUMMER CAULIFLOWER VARIETIES WITH THE LOCAL CULTIVAR

M Nathoo

Agricultural Research Extension Unit

ABSTRACT

Four summer cauliflower varieties (White Contessa, Hybrid Rami, Cashmere and Splendor) were compared in year 2000 with cauliflower cv. Local, which is a traditional winter variety grown in Mauritius. Trials were carried out in two zones; humid and super-humid and included two summer transplanting in March and October and one winter transplanting in July. No significant differences in marketable yield were observed between the planting dates. Interaction effect was observed between planting date and site and between planting date and variety. Therefore better yield can be obtained with these varieties by adjusting the planting date for the respective zones. Cashmere, Hybrid Rami and White Contessa gave good curd yields during the summer transplanting, and had higher curd yields than cv. Local. Hybrid Rami and White Contessa are promising varieties to extend the growing season outside winter period for the market supply in Mauritius. Moreover the yield of Hybrid Rami is higher than the local cultivar in winter and, as their curds are of better quality, they can be considered as potential replacements for the latter.

Keywords: cauliflower, Brassica oleracea L botrytis, planting date, Cashmere, Hybrid Rami, White Contessa, Splendor.

INTRODUCTION

The family Brassicaceae includes a number of vegetables of worldwide importance, and most of these are native to Europe, Middle East or Asia (Pierce,1987). Cauliflower is a highly appreciated crop of the Brassicaceae family which is mostly cultivated in the winter season from March to September where the average minimum and maximum temperatures are 18.5 °C and 26.8 °C respectively. (Anon.,1982). The most popular variety grown is the cv local which is open-pollinated. This variety grows well in a temperature range of 15-25 °C but however no production is possible during the summer months, that is, from October to March. There are three distinct cropping seasons for cauliflower production. These are the early season (January-April), the main season (May-August) and the late season (September to December). Cauliflower is grown for its composite inflorescence referred as its curd. Curd initiation in cauliflower is influenced by a number of factors such as genotype, photoperiod, nitrogen level, temperature and light. However for induction of curd formation apart from low temperature (Sadik, 1960; Sadik, 1967; Atherton, et al., 1987) the plants should also have reached a certain physiological stage (Fujime, 1983; Sadik, 1967; Wiebe, 1972). Nowadays, with advances in breeding programme a number of varieties suitable for different temperature ranges have been developed. Thus genotypic variation has made cultivation of cauliflower possible over a range of climatic conditions (Nieuwhof, 1969; Wurr, et al., 1981). It is therefore important to choose the appropriate variety with respect to climatic condition to enable curd formation. The floral homeotic gene (both and bra1) responsible for curd initiation is very sensitive to temperature and curd initiation at required temperature can shift back to vegetative stage if there is increase in temperature (Anthony et al, 1996). Thus temperature plays an important role in controlling the effect of these genes whose expression can be detected at 18 °C but not at 25 °C. This is the reason why summer varieties from temperate regions tend to remain vegetative when grown in tropical conditions.

The local production for the past ten years shows that the cultivated area for cauliflower and production ranged between 61-227 hectares and 1150-4260 tonnes respectively (Figure 1).
Since 1992 up to 1998 a constant increase in cauliflower production has been noted. However this
trend changed since 1999 where a decrease in area and production has been observed. Furthermore a
yield of 18-20tha\(^{-1}\) has been obtained over time (Table 1).

**Figure 1** Production of cauliflower (1992-2001)

![Production of cauliflower (1992-2001)](image)

Source: Digest of Agricultural Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>Production (T)</th>
</tr>
</thead>
<tbody>
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<td>1992</td>
<td>25.5</td>
<td>1,000</td>
</tr>
<tr>
<td>1993</td>
<td>50.1</td>
<td>2,000</td>
</tr>
<tr>
<td>1994</td>
<td>75.2</td>
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<td>1995</td>
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<td>4,000</td>
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<td>2001</td>
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<td>10,000</td>
</tr>
</tbody>
</table>

The constant yield is due to a single variety, cv local, with hardly any improvement on cultural
practices. However the production of cauliflower in the early season is very much less compared to
the main and late season (Figure 2).

Fluctuation in production has also been influenced by other factors, like cyclone, drought, flood and
pests and diseases. In parallel to this situation, the market retailed prices of cauliflower also fluctuates
over the months as shown in Figure 3.

Uneven production causes gluts and shortages in the supply of cauliflower in the market. To create a
more stable supply, research work on cauliflower has been carried since 1958 (Anon 1960). In 1962
(Anon 1962), results obtained showed that cauliflower could be produced beyond November in the
uplands as long as precautionary measures were taken against droughts, insect pests and diseases. A
Taiwanese variety, *Hs-shu*, was evaluated for summer production in 1973. In 1980, the following
heat tolerant varieties *Snow Peak*, *Hs-shu*, *Farmer’s Early No2* and *Farmer’s Early No3* and *Snow
King* were further tested at different planting dates from September to December on a monthly basis.
Results showed that varieties *Hs-shu*, *Farmer’s Early No2* and *Farmer’s Early No3* could be


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harvested as early as January (Anon 1980). But no further production of these varieties has been carried out leading to the local variety being predominant among growers.

Figure 2 Cauliflower production and area cultivated in the three cropping seasons (1997-2001)
Comparative performance of four summer cauliflower varieties with the local cultivar. M. Nathoo

Figure 3 Price fluctuation 1997 - 2001

Justification of research
AREU has been carrying research on cauliflower since 1996 where 31 varieties (Baisha, Cristina, Elsa, F1 Mont Blanc, Hsihu, Hybrid Rami, Japanese Improved, Snowball, Snowcap, White Contessa, Cashmere, Gipsy, Kestrel, White Rock, Mayflower, Hogar, White Flash, White Corona, White Baron, Milkyway, Incline, Snowflower, Farmer’s Extra Early, Farmers Early No 2, Splendor, Fengshan Extra Early, Indam Early, White Swan, White Corona, Pusa Synthetic and Star 4401) suitable for a range of temperature were evaluated. Through repeated trials four varieties have been pre-selected and were further tested for suitability and seasonality over 2 growing areas.

MATERIALS AND METHODS
Four summer varieties; Cashmere, Hybrid Rami, White Contessa and Splendor, were tested against cv Local as control to assess their yield potential in 2 agro-climatic conditions in three cropping seasons. The trial was carried out in year 2000 at Réduit Crop Research Station (L1) in the humid zone and Wooton Crop Research Station (L2) in the super-humid zone; and included two summer transplanting, in March (P1) and October (P3) and one winter transplanting in July (P2). The soil of L1 belongs to the low humic latosolic type, whereas that of L2 is of the latosolic brown forest type. A 2 x 5 factorial design with three replicates was used for the experiment.

Cauliflower seeds were treated at 50 °C for 15 minutes. They were then sown in small pots containing a mixture of farm yard manure (FYM), soil and sand in the ratio of 3:2:1 supplemented with triple super phosphate (TSP) and muriate of potash (MoP). The seedlings were transplanted at the 4 to 5 leaf stage into plots of 4.05 m² with holes measuring 25x25x20 cm. The spacing used was 75 cm between rows and 60 cm between plants. Each plot consisted of 20 plants surrounded by double guard-rows. A basal fertilizer dressing of 12g triple super phosphate and 12g muriate of potash, together with 1 kg FYM was applied per plant. Each plant was given topdressing of 15g sulphate of ammonia. At curd maturity the following parameters were recorded: fresh weight of plant, curd weight and curd
circumference. Marketable yield, curd compactness \{curd weight \(\text{g}\)/curd circumference \(\text{cm}\)\} and curd to leaf ratio and crop cycle \{planting to harvest \(\text{days}\)\} were derived.

RESULTS AND DISCUSSION

Average maximum and minimum temperatures at the two growing sites are shown in Table 2.

<table>
<thead>
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<th>Planting Date</th>
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<td>min</td>
<td>21.7</td>
<td>22.9</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Table 2 Mean monthly maximum and minimum temperatures (°C) in Réduit and Wooton in year 2000

The average yield, curd weight, curd circumference, curd compactness and curd to leaf ratio are given in Table 3 below.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean marketable yield (\text{t ha}^{-1})</th>
<th>Mean curd weight (\text{kg})</th>
<th>Mean circumference of curd (\text{cm})</th>
<th>Mean curd compactness (\text{g cm}^{-1})</th>
<th>Curd to leaf ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashmere</td>
<td>10.69\textsuperscript{a}</td>
<td>0.481\textsuperscript{b}</td>
<td>43.01\textsuperscript{a}</td>
<td>10.99\textsuperscript{a}</td>
<td>0.636\textsuperscript{b}</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>8.91\textsuperscript{b}</td>
<td>0.415\textsuperscript{b}</td>
<td>40.97\textsuperscript{b}</td>
<td>9.59\textsuperscript{b}</td>
<td>0.466\textsuperscript{c}</td>
</tr>
<tr>
<td>White Contessa</td>
<td>8.23\textsuperscript{b}</td>
<td>0.363\textsuperscript{c}</td>
<td>34.91\textsuperscript{d}</td>
<td>9.63\textsuperscript{b}</td>
<td>0.685\textsuperscript{a}</td>
</tr>
<tr>
<td>Splendor</td>
<td>5.57\textsuperscript{c}</td>
<td>0.251\textsuperscript{d}</td>
<td>32.58\textsuperscript{e}</td>
<td>7.35\textsuperscript{c}</td>
<td>0.697\textsuperscript{c}</td>
</tr>
<tr>
<td>Local</td>
<td>5.25\textsuperscript{c}</td>
<td>0.236\textsuperscript{e}</td>
<td>38.32\textsuperscript{c}</td>
<td>6.04\textsuperscript{d}</td>
<td>0.448\textsuperscript{c}</td>
</tr>
<tr>
<td>S.E ±</td>
<td>0.53</td>
<td>0.026</td>
<td>1.297</td>
<td>0.412</td>
<td>0.043</td>
</tr>
</tbody>
</table>

S.E ± Standard error
* Significant at 5% level

Means within a column followed by different letters are significantly different at 5% level

There was significant differences between varieties for the different parameters measured. The best performance was obtained with Cashmere, which had an average yield of 10.69 \(\text{t ha}^{-1}\), with an average unit curd weighing 481 g, and a mean curd circumference of 43 cm. **Cv Local** was the lowest yielder, 5.25 \(\text{t ha}^{-1}\). **White Contessa** and **Splendor** had a better curd to leaf ratio of above 0.685 indicating that less than 32 % of the total fresh weight is attributed to non-edible part. **Local** and **Hybrid Rami** had the smallest ratio as they have vigorous tall outer leaves protecting the curd.

Marketable yield

Overall marketable yield at Réduit was significantly higher than Wooton for all varieties. All four varieties produce better marketable yield than the **Cv Local** in Réduit. However, **White Contessa** and
Comparative performance of four summer cauliflower varieties with the local cultivar. M. Nathoo

Splendor gave poorer yields than Cv Local and Cashmere, and Hybrid Rami produced the best yield at both sites.

Interaction effect was observed between planting date and variety. P2 was most suitable for Cashmere and Hybrid Rami for both sites. However, White Contessa P2 was most suitable for Réduit and not for Wooton. P3 was most suitable for White Contessa and Splendor at Wooton. Finally the Cv Local was suitable at both sites for P1. (Table 5)

Table 4 Mean marketable yield (t ha⁻¹) of cauliflower in two growing sites over 3 planting dates

<table>
<thead>
<tr>
<th>Variety</th>
<th>Réduit (L1)</th>
<th>Wooton (L2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>Cashmere</td>
<td>11.39</td>
<td>11.84</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>10.31</td>
<td>12.57</td>
</tr>
<tr>
<td>White Contessa</td>
<td>10.48</td>
<td>11.93</td>
</tr>
<tr>
<td>Splendor</td>
<td>7.71</td>
<td>7.09</td>
</tr>
<tr>
<td>Local</td>
<td>8.71</td>
<td>4.44</td>
</tr>
<tr>
<td>Mean</td>
<td>9.72</td>
<td>9.57</td>
</tr>
</tbody>
</table>

SE ± Planting Date: 0.77 1.61
SE ± Variety: 0.99 2.08

Table 5 Suitability of the varieties based on marketable yield

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Réduit</th>
<th>Wooton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>Cashmere</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>White Contessa</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Splendor</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Local</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

S.E. ± Standard error * : Significant at 5% level

* suitable, - not suitable

Cashmere, Hybrid Rami and White Contessa gave marketable yield above control at planting dates P1 and P2 in Réduit CRS. However, at the same planting dates White Contessa had marketable yield below control at Wooton CRS. Similarly, the highest yield (12.87 t ha⁻¹) was obtained with Cashmere in Réduit at planting date P3, when White Contessa gave the best yield (11.35 t ha⁻¹) at Wooton. Therefore better yield can be obtained by adjusting the planting dates. White Contessa and Splendor gave the lowest yield in winter at Wooton CRS. This is probably due to the prevailing low temperature at Wooton CRS which initiated premature flowering of these two summer varieties. This confirms the findings of Gauss and Taylor (1969) who noted that low temperature retarded vegetative growth so that the plant underwent differentiation and formed buttons at a young morphological age. Buttoning also occurred in early summer cultivars when curd initiation and development happens before the plant has developed sufficient leaves to support full development of the curd (Carew and Thompson, 1948; Wurr et al., 1984)
Weight of curd

No significant differences in curd weight were observed between the planting dates. Therefore the curd weight of the varieties tested is not dependent on planting dates. The same response was observed for curd compactness. Better results were obtained at Reduit compared to Wooton. There is a significant difference in the curd weight between varieties with Cashmere performing better than Hybrid Rami and White Contessa.

All varieties were better than Cv Local at both sites where Cashmere and Hybrid Rami gave the the highest mean curd weight.

At Wooton White Contessa and Splendor gave the lowest curd weight in winter. At Réduit Cashmere, Hybrid Rami and White Contessa gave significantly higher yields than the local variety. The low production of local from the summer sowings was due to high leaf production and a button-sized curd.

Table 6 Mean curd weight of cauliflower (kg) in two growing sites over 3 planting dates

<table>
<thead>
<tr>
<th>Variety</th>
<th>Réduit (L1)</th>
<th>Wooton (L2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planting Date</td>
<td>Planting Date</td>
</tr>
<tr>
<td>Cashmere</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>Hybrid Ram</td>
<td>0.513</td>
<td>0.533</td>
</tr>
<tr>
<td>White Contessa</td>
<td>0.472</td>
<td>0.544</td>
</tr>
<tr>
<td>Splendor</td>
<td>0.347</td>
<td>0.319</td>
</tr>
<tr>
<td>Local</td>
<td>0.392</td>
<td>0.200</td>
</tr>
<tr>
<td>Mean</td>
<td>0.437</td>
<td>0.426</td>
</tr>
</tbody>
</table>

SE ± Planting Date: 0.030 | 0.070
SE ± Variety: 0.040 | 0.090

Table 7 Mean circumference of curd of cauliflower (cm) in two growing sites over 3 planting dates

<table>
<thead>
<tr>
<th>Variety</th>
<th>Réduit (L1)</th>
<th>Wooton (L2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planting Date</td>
<td>Planting Date</td>
</tr>
<tr>
<td>Cashmere</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>Hybrid Ram</td>
<td>48.0</td>
<td>44.3</td>
</tr>
<tr>
<td>White Contessa</td>
<td>45.7</td>
<td>47.5</td>
</tr>
<tr>
<td>Splendor</td>
<td>41.2</td>
<td>40.3</td>
</tr>
<tr>
<td>Local</td>
<td>48.2</td>
<td>42.2</td>
</tr>
<tr>
<td>Mean</td>
<td>45.1</td>
<td>44.0</td>
</tr>
</tbody>
</table>

SE ± Planting Date: 1.64 | 4.23
SE ± Variety: 2.11 | 5.46

SE ± Standard error: * Significant at 5% level
There were significant differences in the curd circumferences among the planting dates as well as among the varieties tested. The same response was observed for curd to leaf ratio. Interaction effect was observed between planting date and site, between planting date and variety, and between site and variety. The same response was observed for curd compactness.

Curd circumference was superior in Reduit than Wooton. Therefore cauliflower performed better at Reduit. Bigger curds were obtained with Hybrid Rami in winter at Reduit compared to the Local variety while at Wooton bigger curds were obtained with Hybrid Rami, Cashmere and Local in winter. (Table 8)

Table 8 Suitability of the varieties based on size

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Reduit</th>
<th></th>
<th></th>
<th>Wooton</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>Cashmere</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>-</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>*</td>
</tr>
<tr>
<td>White Contessa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>*</td>
</tr>
<tr>
<td>Splendor</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>-</td>
</tr>
<tr>
<td>Local</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* suitable, - not suitable

Very small curds were produced by White Contessa and Splendor. As already mentioned the ability of the plant to flower depends on the genetical make-up and the environmental factors. Unfavorable environmental conditions, like low winter temperature at Wooton, (see Table 2) can give rise to buttoning (an unwanted physiological disorder). This phenomenon is particularly important in early summer cauliflower eg White Contessa and Splendor.

Curd compactness

Table 9 Mean curd compactness (g/cm) of cauliflower in two growing sites over 3 planting dates

<table>
<thead>
<tr>
<th>Variety</th>
<th>Reduit (L1)</th>
<th></th>
<th></th>
<th>Wooton (L2)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planting Date</td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>Mean</td>
<td>P1</td>
</tr>
<tr>
<td>Cashmere</td>
<td>10.69</td>
<td>11.90</td>
<td>13.50</td>
<td>12.00</td>
<td>8.01</td>
<td>12.89</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>10.14</td>
<td>11.66</td>
<td>9.30</td>
<td>10.40</td>
<td>7.75</td>
<td>9.85</td>
</tr>
<tr>
<td>White Contessa</td>
<td>10.31</td>
<td>11.30</td>
<td>11.84</td>
<td>11.20</td>
<td>7.02</td>
<td>3.14</td>
</tr>
<tr>
<td>Splendor</td>
<td>8.45</td>
<td>7.90</td>
<td>7.52</td>
<td>7.96</td>
<td>6.19</td>
<td>4.59</td>
</tr>
<tr>
<td>Local</td>
<td>8.03</td>
<td>4.73</td>
<td>4.54</td>
<td>5.77</td>
<td>8.11</td>
<td>6.12</td>
</tr>
<tr>
<td>Mean</td>
<td>9.54</td>
<td>9.50</td>
<td>9.34</td>
<td>9.45</td>
<td>7.42</td>
<td>7.32</td>
</tr>
<tr>
<td>SE ± Planting Date</td>
<td>0.63</td>
<td>*</td>
<td>*</td>
<td>0.63</td>
<td>1.46</td>
<td>*</td>
</tr>
<tr>
<td>SE ± Variety</td>
<td>0.82</td>
<td>1.88</td>
<td>*</td>
<td>*</td>
<td>0.82</td>
<td>1.88</td>
</tr>
</tbody>
</table>

* Significant at 5% level

Curd compactness is measured as the ratio of curd weight to curd circumference. There was a significant difference in the curd compactness among the varieties tested. Cashmere, Hybrid Rami and White Contessa had relatively higher curd compactness than Local. These varieties are better in Reduit than Wooton.
Curd to leaf ratio

Table 10 Mean curd to leaf ratio of cauliflower in two growing sites over 3 planting dates

<table>
<thead>
<tr>
<th>Variety</th>
<th>Réduit (L1)</th>
<th></th>
<th></th>
<th></th>
<th>Wooton (L2)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>Mean</td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>Mean</td>
</tr>
<tr>
<td>Cashmere</td>
<td>0.72</td>
<td>1.04</td>
<td>0.35</td>
<td>0.70</td>
<td>0.53</td>
<td>0.81</td>
<td>0.37</td>
<td>0.646</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>0.38</td>
<td>0.73</td>
<td>0.23</td>
<td>0.45</td>
<td>0.48</td>
<td>0.58</td>
<td>0.39</td>
<td>0.462</td>
</tr>
<tr>
<td>White Contessa</td>
<td>0.91</td>
<td>1.15</td>
<td>0.31</td>
<td>0.79</td>
<td>0.39</td>
<td>0.19</td>
<td>0.85</td>
<td>0.655</td>
</tr>
<tr>
<td>Splendor</td>
<td>0.84</td>
<td>0.83</td>
<td>0.84</td>
<td>0.84</td>
<td>0.91</td>
<td>0.24</td>
<td>0.51</td>
<td>0.715</td>
</tr>
<tr>
<td>Local</td>
<td>0.53</td>
<td>0.43</td>
<td>0.39</td>
<td>0.45</td>
<td>0.57</td>
<td>0.36</td>
<td>0.41</td>
<td>0.449</td>
</tr>
<tr>
<td>Mean</td>
<td>0.676</td>
<td>0.835</td>
<td>0.424</td>
<td>0.45</td>
<td>0.576</td>
<td>0.436</td>
<td>0.506</td>
<td></td>
</tr>
<tr>
<td>SE ± Planting Date</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE ± Variety</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE ± Standard error
* : Significant at 5% level

At L1 White Contessa had the highest curd to leaf ratio in winter. While at the same locality in late summer Cashmere, Hybrid Rami and White Contessa are very leafy. This is probably due to the high temperature of the summer months.

Crop cycle

The crop cycle for the different varieties was also obtained from first to last harvests at the two localities.(Table 11)

Table 11 Crop cycle and curd colour

<table>
<thead>
<tr>
<th>Variety</th>
<th>Crop cycle (days)</th>
<th>Colour of curd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashmere</td>
<td>65 - 75</td>
<td>pure white</td>
</tr>
<tr>
<td>Hybrid Rami</td>
<td>60 - 70</td>
<td>creamy</td>
</tr>
<tr>
<td>White Contessa</td>
<td>50 - 60</td>
<td>white</td>
</tr>
<tr>
<td>Splendor</td>
<td>50 - 55</td>
<td>white</td>
</tr>
<tr>
<td>Local</td>
<td>70 - 75</td>
<td>light yellow</td>
</tr>
</tbody>
</table>

The crop cycle of Splendor, White Contessa and Hybrid Rami are below Cashmere and Local. White Contessa and Splendor had the shortest crop cycle of 50-55 days only. The four summer varieties are whiter in curd color than cv Local. Cauliflower with white to creamy curd is most preferred by the local consumers.

CONCLUSION

1. Cashmere is better in all the characters measured. It can be grown in all three planting seasons in humid zone. Unfortunately it has a rather long crop cycle (65-70 days) compared to the other varieties.
2. The yield of Hybrid Rami is higher than that of Cv Local and, as its curds are of better quality, it can be considered as potential replacement for the latter in winter.
3. White Contessa performed well in the humid season for the early and main season and in the super humid zone for the late season.
4. Splendor is comparable to Cv Local in the super humid zone for the early season.
5. Hybrid Rami, White Contessa, Cashmere and Splendor are promising varieties to extend the growing season outside winter period for the market supply in Mauritius.
6. In light of the results obtained from the experiment the following varieties are recommended at the different planting dates or cropping seasons (Table 12).

Table 12 Recommended varieties

<table>
<thead>
<tr>
<th></th>
<th>Early Season (P1)</th>
<th>Main season (P2)</th>
<th>Late season (P3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid zone</td>
<td>Cashmere, White Contessa, Splendor, Local</td>
<td>Cashmere, Hybrid Rami, White Contessa, Splendor</td>
<td>Cashmere, Splendor</td>
</tr>
<tr>
<td>Super-humid zone</td>
<td>Splendor, Local</td>
<td>Cashmere, Hybrid Rami, Local</td>
<td>White Contessa, Splendor</td>
</tr>
</tbody>
</table>

ACKNOWLEDGEMENTS

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Comparative performance of four summer cauliflower varieties with the local cultivar. M. Nathoo


ABSTRACT

Lack of water is one of the main limiting factors in the production of tomato in Mauritius. The aim of this study was to assess the yield response of two popular tomato varieties MST 32/1 and Sirius to deficit irrigation. Two trials were carried out at Pamplemousses in 1999 and 2000. Results showed a curvilinear relationship (yield = -0.002x^2 + 0.11x – 2.5; r^2 = 0.88, x = water received) with about 300 mm of water giving the highest yield of 15.5 t ha^{-1}. It was found that yield response to irrigation decreased markedly beyond the 0.75 ETc regime due to deep percolation losses and a decrease in the harvest index. Whether water is limiting or not, it may be better to irrigate at 0.75 ETc so as to limit the amount of rotten fruits and to optimise fruit size and quality as well as yield.

Keywords: fruit quality, evapotranspiration, water use efficiency

INTRODUCTION

In Mauritius, fresh market tomato is grown throughout the year. The average annual production of cooking tomato is about 13 000 tonnes with an average yield of about 11 t ha^{-1} (CSO, 1997). The crop is mostly grown by small-scale planters (Govinden et al. 1997a) and most plantations are in the North where growing conditions are considered to be the best compared to the rest of the island. However, the rainfall of about 1450 mm per year in that region (Padya 1984) is not well distributed and a lack of water arises during the drier months. As mentioned by Govinden et al. (1997b), the scarcity of water for irrigation is one of the main limiting factors for tomato cultivation. Planters have then to resort to some form of deficit irrigation.

Deficit irrigation is a deliberate and systematic under-irrigation of crops and is a common practice in many parts of the world (English and Raja 1996). It consists of irrigating at rates that are less than the rate of water loss through evapotranspiration. Depending on the amount of water-deficit, the plant is more or less stressed and plant growth and development are reduced. It is important to determine the extent to which the plant may be stressed so as to optimize the yield.

The aim of this study was to assess the yield response of tomato to deficit irrigation and hence to determine the water required to optimize yield and fruit quality.

MATERIALS AND METHODS

The two most popular varieties in Mauritius were grown: MST 32/1 and Sirius. These varieties have been developed by the MSIRI for field cultivation under Mauritian conditions. The average yields obtained from these varieties range from 10 to 25 t ha^{-1}. MST 32/1 is a semi-determinate variety while Sirius is a determinate one. Their average fruit size is about 80 g and they have a crop cycle of 3 to 3.5 months.

Two trials were carried out at Pamplemousses, one in the summer of 1999 and the other in the winter of 2000 with a fallow period of three months between the two trials. The soil is of the Low Humic Latosol group with Total Available Water (TAW) of 45 mm and Readily Available Water (RAW) of...
28 mm at a root depth of 45 cm. The saturated hydraulic conductivities were of the order of 18.5 mm h\(^{-1}\), 12.5 mm h\(^{-1}\), and 3.2 mm h\(^{-1}\) for soil depths of 15, 30 and 45 cm respectively.

The experimental design used was a split-plot with four replicates. The main plots consisted of five irrigation regimes calculated from the evapotranspiration rate of the crop (ET\(_c\)): 0, 0.5, 0.75, 1.0 and 1.25 ET\(_c\). The sub-plots consisted of the two varieties. Each plot consisted of 14 rows (7 rows for each variety), 10 m long, and spaced at 1 m. The intra-row spacing was 0.5 m, giving a crop density of 20 000 plants ha\(^{-1}\). Fertilization and other crop husbandry practices were as recommended by Govinden et al. (1995) for commercial tomato production.

In 1999, seedlings were transplanted into holes that had previously been fertilized. In 2000, five to seven seeds were sown per hole and when the seedlings were about 10 cm high (three weeks after sowing), they were thinned to one plant per hill. In both trials, irrigation was applied ad-lib to favour germination and early establishment of the seedlings during the seedling stage.

Irrigation regimes were applied after the seedling stage using a solid-set sprinkler system made up of spraying units. Each spraying unit consisted of two full-jet nozzles held in place by a T-shaped structure 1.6 m wide and 2 m tall. Each irrigated plot had nine such spraying units and one valve for controlling the timing of irrigation. At an operating pressure of about 140 kPa, the system applied 70 mm h\(^{-1}\). The 10 inner rows of each plot were irrigated.

Climatic data were obtained from a meteorological station on the site and weekly values of evapotranspiration were calculated using the Penman equation (Penman, 1963). Hence, the weekly crop evapotranspiration (ET\(_c\)) for the different crop growth stages was determined using the appropriate crop factors adapted from Doorenbos and Pruitt (1977). Water amounts corresponding to the requirements for the different treatments were then applied. The moisture content of soil layers 0-20 cm, 20-40 cm, and 40-60 cm were monitored with a Time Domain Reflectometry (TDR) soil moisture probe (Heimovaara, 1993).

Fruits were harvested when they started to ripen. Each row was harvested separately; its fruits were counted, separated into marketable and rotten and then weighed. Harvest was done on a weekly basis. Moreover, the dry matter of stems, leaves and fruits was determined using 2-plant samples on a fortnightly basis.

RESULTS AND DISCUSSION

Water received

The amount of water received by the different treatments is shown in Table 1. The trial received more water in 1999 than in 2000. This was because 1999 was drier than 2000 and also the trial in 1999 was carried out in summer while that of 2000 was in winter.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Year 1999 trial</th>
<th>Year 2000 trial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigation</td>
<td>Rainfall</td>
</tr>
<tr>
<td>Rainfed</td>
<td>-</td>
<td>60</td>
</tr>
<tr>
<td>0.50 ET(_c)</td>
<td>114</td>
<td>60</td>
</tr>
<tr>
<td>0.75 ET(_c)</td>
<td>176</td>
<td>60</td>
</tr>
<tr>
<td>1.00 ET(_c)</td>
<td>237</td>
<td>60</td>
</tr>
<tr>
<td>1.25 ET(_c)</td>
<td>299</td>
<td>60</td>
</tr>
</tbody>
</table>
The response of fruit yield to the amount of water received

The effect of water received on yield is illustrated in Figure 1. It shows a curvilinear relationship (yield = -0.002 $x^2 + 0.11x - 2.5$; $x =$ water applied, $r^2 = 0.88$), reaching an optimum at about 300 mm with a yield of 15.5 t ha$^{-1}$.

Figure 1 Yield response to water

The plateau in yield observed thereafter at the higher irrigation regimes may be attributed either to a lower water use efficiency (WUE) of the plant or to the loss of water through deep percolation or to a combination of both.

Soil moisture below the root zone

Water variability in the 40-60 cm layer of the soil, as monitored by the TDR soil moisture probe in the 1999 trial, is illustrated in Figure 2. At the onset of the trial, the soil was saturated as a result of irrigation to boost up crop growth during the seedling establishment phase and this explains the initial peak in the graph. Subsequently, there was a stabilization of the soil moisture levels until the irrigation regimes were applied.

In the 0.75, 1.0 and 1.25 ETc treatments, regular patterns of replenishment and depletion were observed, indicating water movement below the root zone; as opposed to the two drier regimes in which no such changes in soil moisture were apparent. This loss of water by deep percolation was more accentuated in the 1.0 and 1.25 ETc treatments, as shown by the greater amplitudes of the peaks. This partly explains the lower WUE observed in those two treatments.

Plant growth analysis

Plant growth analysis was used to study the response of the plant to water applied. The effect of the amount of water applied on the harvest index (HI), which is the ratio of fruit weight to plant biomass, was determined.

HI was constant for the rainfed up to 0.75 ETc treatment, and decreased with the highest irrigation regimes. The plant biomass, however, continued to increase (Figure 3). This, therefore, also explains the decline in WUE that occurred in the wettest treatments.
Yield response of fresh market tomato (*Lycopersicon esculentum* Mill) to deficit irrigation. *K Rummun* et al.

Figure 2 Soil moisture profile in the 40 to 60 cm layer in the 1999 trial

![Soil moisture profile graph](image)

Figure 3 Response in biomass and harvest index to water applied

![Biomass and harvest index graph](image)
Fruit quality

Plant growth analysis also showed that fruit weight increased with the amount of water (fruit yield = 7.4 x + 33.778, r² = 0.9412), reaching about 25% more at 1.25 ETc. Consumers are known to prefer bigger fruits.

Fruit quality was, nevertheless, affected by irrigation. More rotting was observed in the irrigated treatments than in the rainfed treatment. However, there was no direct relationship between fruit rot and irrigation level, an indication that irrigation does not induce rotting but rather indirectly enhances it. In fact, most of the rotting occurred at the beginning of the harvest period because there had been an attack of insects on the fruits. The presence of water on the fruits favoured the development of secondary infections, thus increasing the number of rotten fruits in irrigated treatments. Once the insects were controlled through the use of pesticides, the number of rotten fruits decreased to similar levels in all treatments. Had the fruits been kept dry, through the use of drip irrigation for example, the number of rotten fruits would not have been higher than that in the rainfed treatment.

CONCLUSION

In these trials, the highest yield was obtained using about 300 mm of water for the crop cycle. When water is limiting, it is best to irrigate at 0.75 ETc because the HI decreases markedly after 0.75 ETc. Furthermore, at 1.0 ETc and 1.25 ETc, water is lost below the root zone through deep percolation, hence further decreasing the WUE. Even when water is not limiting, it is best to irrigate at 0.75 ETc so as to limit the amount of rotten fruits and to optimise fruit size and quality.

ACKNOWLEDGEMENTS

We are grateful to the Field Officer in charge of Pamplemousses Experiment Station of the MSIRI and colleagues of the Irrigation Department for their support. We would also like to thank the Director and Deputy Director of MSIRI for their valuable comments.

REFERENCES


Yield response of fresh market tomato (Lycopersicon esculentum Mill) to deficit irrigation. K Rummun et al.


ASSESSING THE NEED FOR OPTIMIZING THE FERTILIZER RECOMMENDATION FOR ONION IN MAURITIUS.

Y Cadersa and A Atawoo

ABSTRACT

Onion is currently grown on different soil types ranging from acidic upland soils to the coral sandy soils of the littoral. A survey on the nutrient status of the soil was undertaken in the major growing regions from June to December 1999. The levels of the major nutrients (N, P, K) were found to be above optimum at La Marie / Glen Park, Plaine Sophie and La Ferme / St Martin while at Belle Mare / Palmar, they were at intermediate levels. Subsequently, two trials; one at Réduit and the other at Wooton were conducted in 2000 to evaluate the effect of six levels of nitrogen (N) and three levels of potassium (K) on the yield and uptake of major nutrients in the onion variety Star 5504. The present fertilizer recommendation was used as control. The results indicated that increasing the N level from 0 to 120.75 kg ha\(^{-1}\) increased bulb yield significantly at Wooton but not at Réduit whereas when the K level was increased from 0 to 86.4 kg ha\(^{-1}\), bulb yield increased significantly at Réduit. At both sites, at the bulbing stage, the nutrients (N, P and K) in the youngest fully expanded leaves (YFEL) were optimal irrespective of fertilizer levels. At Wooton, a significant and linear relationship was obtained between total N supply and N uptake in bulbs (r = 0.94) while at Réduit the relationship was not significant. Therefore, this study showed that there is a need to review the present fertilizer recommendation especially with respect to N and K.

Keywords: onion, fertilizer, nutrient levels, uptake, bulb yield

INTRODUCTION

Onion (Allium cepa) is one of the main vegetable crops grown in Mauritius. It covers an area of 320 hectares with an average annual production of around 10,000 tonnes (Anon, 2001). It is currently being cultivated under different agro climatic conditions and on different soil types, from the acidic soils of the highlands to the alkaline sandy soils of the littoral. This is possible due to the availability of several onion varieties, which are suited to the various agro climatic areas of the island. In many countries, fertilizer recommendation in onion is site or area specific. The recommendation is based on several factors such as previous cropping, soil type, fertility level and variety to be grown. In addition during the growth stage, leaf or sap analysis is performed to determine the deficiency or adequacy of a particular nutrient (FAO, 1986). However, in Mauritius, the current fertilizer recommendation for onion is applicable islandwide, without consideration for local variations in soil conditions including nutrient levels and precipitation rate. In fact, this recommendation dates some 25 years back (Anon, 1986) when onion varieties cultivated, were very different from the recently introduced high yielding ones.

Since fertilizer is a major input in the production process, there is a need to rationalize its use as an underutilization can lead to sub optimal yield. On the other hand, when used excessively, it can reduce yield, affect post harvest quality and constitute a threat to the environment with respect to surface and ground water pollution.

This study was undertaken to assess the need for optimizing the fertilizer recommendation for onion. Therefore, the main objectives were:

(i) to determine the nutrient status of the soil in the main onion growing regions
(ii) to assess the influence of different levels of nitrogen (N) and potassium (K) fertilizers on the nutrient uptake and removal in onion; and hence
(iii) to test the validity of the present fertilizer recommendation.
MATERIALS AND METHODS

Determination of the nutrient status of the soil

This activity was carried out from June to December 1999 in 4 main onion-growing regions namely La Marie / Glen Park, Plaine Sophie, La Ferme / St Martin and Belle Mare / Palmar. In each region, based on the area planted, a given number of fields were randomly selected prior to soil sampling (Table 1). In each of the selected fields, 10 random samples were taken at a depth of 20 cm with a round auger of 10 cm diameter. The samples were thoroughly mixed to produce a single composite sample, which was thus used for analytical purposes.

Experimental trials

Two trials were laid down in Mauritius (20° S latitude, 57° E longitude), one at Réduit and one at Wooton in 2000 using the onion variety Star 5504 in a randomized complete block design with 3 replicates. The soil at Réduit is of Low Humic Latosols (LHL) while that of Wooton of Latosolic Reddish Prairie (LRP).

In all trials, maize was planted to deplete the soil before starting the fertilizer trials. Poultry manure was applied at the rate of 25 t ha⁻¹ following land preparation. At Réduit and Wooton Experimental Stations, 6 levels of nitrogen (0, 24.15, 43.3, 72.45, 96.6 and 120.75) kg N ha⁻¹ and 3 levels of potassium (0, 43.2 and 86.4 kg K₂O ha⁻¹) were used. Nitrogen was applied as ammonium sulphate (21% N) and potassium as sulphate of potash (48% K₂O). A basal application of 55.2 kg ha⁻¹ P₂O₅ applied as triple superphosphate was used at both sites. Nitrogen at 72.45 kg ha⁻¹ and potassium at 86.4 kg ha⁻¹ were used as recommended rates. Cultural practices (weeding, irrigation and pest and disease control) were as recommended for commercial plantations (Anon, 1998).

Destructive leaf sampling from 5 selected plants / plot was carried out at the youngest fully expanded stage (just before bulbing) to determine the nutrient uptake and hence to have an indication of the N, P and K status in the leaf. At harvest, the crop performance was assessed in terms of marketable bulb yield. Onion bulbs were oven dried at 70°C and dry matter and nutrient analysis (% N, P and K) were performed to determine the nutrient uptake by the onion crop. Soil samples were dried, sieved through 4 mm mesh and analyzed for pH, total nitrogen (%), available phosphorus and potassium as described by Buurman et al (1996).

RESULTS AND DISCUSSION

Nutrient / soil fertility status

The mean soil pH at La Marie / Glen Park and Plaine Sophie was slightly acidic with a mean of 6.3. At La Ferme / St Martin, the pH was around 7.3 whereas for the coral sand derived soils of Belle Mare / Palmar, the pH was alkaline with a mean of 8.3 (Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Soil nutrient status in the main onion growing regions in 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Soil group</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>HFL*</td>
</tr>
<tr>
<td>12</td>
<td>HFL</td>
</tr>
<tr>
<td>6</td>
<td>LRP**</td>
</tr>
<tr>
<td>6</td>
<td>Regosols coral sand</td>
</tr>
</tbody>
</table>

* HFL – Humic Ferruginous Latosols ** LRP – Latosolic Reddish Prairie

The soil nutrient status varied from 0.46 – 1.00% N, 17.3 – 582.6 ppm P and 0.12 – 1.17 me% K (Table 1). According to the soil analysis guide for onion, the soil nutrient levels for total N, available phosphorus and potassium at sufficiency level are: > 0.5%, >15 ppm and > 0.3 me % respectively (FAO, 1983). The results showed that the soil nutrient levels were above the optimum in all regions except Belle Mare/Palmar where the soil nutrients for total N (%) and available K (me %) were considered as intermediate levels.

The mean pH of soil at the two experimental sites was slightly acidic while the nutrient levels were above optimum (Table 2). This showed that even one crop cycle of maize was not enough to deplete the soil nutrients to a relatively low level.

**Table 2** Soil characteristics of experimental sites

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Réduit</th>
<th>Wooton</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHL *</td>
<td>5.50</td>
<td>6.30</td>
</tr>
<tr>
<td>HFL **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.50</td>
<td>6.30</td>
</tr>
<tr>
<td>Total (N%)</td>
<td>1.60</td>
<td>1.09</td>
</tr>
<tr>
<td>Available P (ppm)</td>
<td>24.30</td>
<td>42.50</td>
</tr>
<tr>
<td>Available K (me %)</td>
<td>0.45</td>
<td>0.48</td>
</tr>
<tr>
<td>Total rainfall (mm)</td>
<td>252.50</td>
<td>625.30</td>
</tr>
</tbody>
</table>

* LHF- Low Humic Latosols  ** HFL - Humic Ferruginous Latosols

**Effect of different levels of N and K fertilizers on:**

**Bulb yield**

The lower bulb yield at Wooton compared to Réduit could be due to excessive rainfall during the crop cycle and long period of water saturated conditions (Table 2). At Wooton, increasing the N level from 0 to 120.75 kg ha⁻¹ increased bulb yield significantly (20.6 v/s 26.8 tha⁻¹) whereas at Réduit, no yield increase was observed. The relatively higher yield (37.6 tha⁻¹) at the zero application rate might be ascribed to the very high pool of N in the soil such that yield response to the increasing fertilizer application is reduced. The application of 86.4 K₂O ha⁻¹ increased bulb yield by 18% at Réduit while bulb yield decreased by 6.8% at Wooton (Table 3).

**Table 3** Summary table for marketable bulb yield (t ha⁻¹) of onion variety Star 5504 at 6 levels of N and 2 levels of K fertilizers at Réduit and Wooton in 2000

<table>
<thead>
<tr>
<th>N levels (Kg ha⁻¹)</th>
<th>Wooton</th>
<th>Réduit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20.1</td>
<td>34.1</td>
</tr>
<tr>
<td>24.15</td>
<td>22.2</td>
<td>37.3</td>
</tr>
<tr>
<td>43.30</td>
<td>19.5</td>
<td>41.2</td>
</tr>
<tr>
<td>72.45*</td>
<td>20.6</td>
<td>28.7</td>
</tr>
<tr>
<td>96.60</td>
<td>19.3</td>
<td>32.7</td>
</tr>
<tr>
<td>120.75</td>
<td>20.3</td>
<td>28.9</td>
</tr>
<tr>
<td>Mean</td>
<td>23.2</td>
<td>36.2</td>
</tr>
</tbody>
</table>

*Current fertilizer recommendation: Mean followed by the same letter are not significantly different by DMRT at the 5% level of significance

The above results are in line with the findings of Currah and Proctor, (1990) and Alers- alers et al.(1979) who found no response of applied fertilizer in onion in the tropics where the soils are already of high fertility because of their previous cropping history.
Uptake of nutrients in leaf

The percentage (%) uptake of nutrients in the YFEL at the bulbing stage ranged from 2.76 – 4.58 %N, 0.34 – 0.39 % P and 2.48 – 3.92 % K respectively (Table 4). These results are in accordance to those of Malachowki (1947a) who found that the optimal leaf nutrient content in onion was 1.6 – 3.7 % N, 0.31 – 0.42% P and 4.1 - 6.75 % K respectively. Therefore, at both Réduit and Wooton particularly for nutrients N and P, irrespective of fertilizer levels, they were already at optimal level in the leaf. This may also explain why there was no apparent increase in nutrient levels with increasing levels of N and K fertilizers since at the zero level, the nutrients were already at optimal level.

<table>
<thead>
<tr>
<th>N level (kg ha⁻¹)</th>
<th>Réduit Mean ± SE</th>
<th>Wooton Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>0.00</td>
<td>2.76 ± 0.14</td>
<td>0.34 ± 0.01</td>
</tr>
<tr>
<td>24.15</td>
<td>3.37 ± 0.11</td>
<td>0.34 ± 0.02</td>
</tr>
<tr>
<td>43.30</td>
<td>3.53 ± 0.22</td>
<td>0.35 ± 0.02</td>
</tr>
<tr>
<td>72.45</td>
<td>3.57 ± 0.25</td>
<td>0.35 ± 0.02</td>
</tr>
<tr>
<td>96.60</td>
<td>3.83 ± 0.29</td>
<td>0.34 ± 0.01</td>
</tr>
<tr>
<td>120.75</td>
<td>4.58 ± 0.28</td>
<td>0.36 ± 0.02</td>
</tr>
</tbody>
</table>

Uptake of nutrients in bulbs

At both sites, the nutrient levels in the bulbs showed a fluctuating pattern as level of N was increased. These ranged from 1.57 – 2.09 % N, 0.25 – 0.35 % P and 1.56- 1.79 % K (Figure 1). However, a gradual decrease in the nutrient levels was observed as the level of K was increased to 86.4 kg ha⁻¹. At Réduit, there was a slight variation in the quantity (kg ha⁻¹) of N, P and K removed by the onion bulbs between the different N levels. This was also reflected by the dry matter yield which varied between 2.26 to 2.82 t ha⁻¹ (Table 6). Under the range of conditions tested and averaged over N fertilizer levels, the uptake of nutrients in the bulbs calculated at 33 t ha⁻¹ was around 48 kg N ha⁻¹, 8 kg P₂O₅ ha⁻¹ and 45 kg K₂O ha⁻¹. These figures are very close to those found by Zink (1966) and Vimala and Yeong (1994).

At Wooton, the amount of N removed in the bulbs increased by 50.9 % when the N fertilizer level was increased from 24.15 to 120.75 kg ha⁻¹. Dry matter yield also increased but no clear-cut trend could be observed with either P or K removal (Table 5). The positive response may be attributed to the excessive rainfall, which could have leached the N fertilizer and consequently, the additional N input could have been taken up by the plants although the soil fertility was at a high level.

Relation between soil and fertilizer N uptake

Numerous experimental evidence using labelled fertilizer have shown that a plant will take up N from the soil and fertilizer in direct proportion to the available amounts of N in each source (IAEA, 1990). Based on these assumptions, the N uptake by the onion plant from both soil and fertilizer was calculated for both trials. At Réduit, as the N fertilizer level was increased, the amount of N taken up from the soil was less than the amount taken up by the control indicating a negative priming (Table 6). At both sites, the N uptake from the applied fertilizer was very low (5 – 6 %).

The relationship between total N supply and N uptake in the bulbs was studied at Réduit and Wooton in order to verify the efficiency of nitrogen use. The significant linear correlation coefficient at Wooton indicated that 88% of the variation in N uptake was accounted for by the linear function of the amount of total N present in the soil. However, at Réduit, the absence of a relationship showed that the soil N input was very high (Figure 2).
**Figure 1** Trend in N, P, K uptake (%) in onion bulbs at different levels of N (kg ha\(^{-1}\)) at Réduit and Wooton in 2000

**Table 5** Dry matter yield (t ha\(^{-1}\)) and nutrient uptake in onion bulbs at different levels of N at Réduit and Wooton in 2000

<table>
<thead>
<tr>
<th>N level (kg ha(^{-1}))</th>
<th>Réduit</th>
<th>Wooton</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>0.00</td>
<td>54.44</td>
<td>9.87</td>
</tr>
<tr>
<td>24.15</td>
<td>42.53</td>
<td>6.80</td>
</tr>
<tr>
<td>43.30</td>
<td>42.94</td>
<td>7.23</td>
</tr>
<tr>
<td>72.45</td>
<td>44.43</td>
<td>7.92</td>
</tr>
<tr>
<td>96.60</td>
<td>50.99</td>
<td>8.05</td>
</tr>
<tr>
<td>120.75</td>
<td>56.99</td>
<td>7.67</td>
</tr>
<tr>
<td>SD ±</td>
<td>6.27</td>
<td>1.06</td>
</tr>
</tbody>
</table>
Assessing the need for optimizing the fertilizer recommendation for onion in Mauritius. Y. Cadersa and A. Atawoo

Table 6 The effect of N fertilizer application on the uptake of N from the soil at Réduit and Wooton in 2000.

<table>
<thead>
<tr>
<th></th>
<th>Réduit</th>
<th>Wooton</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilizer treatments</strong></td>
<td>0 24 43 72 97 121</td>
<td>0 24 43 72 97 121</td>
</tr>
<tr>
<td><strong>Soil N supply</strong></td>
<td>652 652 652 652 652 452</td>
<td>452 452 452 452 452 452</td>
</tr>
<tr>
<td><strong>Fertilizer N supply</strong></td>
<td>0 24 43 72 97 121</td>
<td>0 24 43 72 97 121</td>
</tr>
<tr>
<td><strong>Total N supply</strong></td>
<td>652 676 695 724 773 452</td>
<td>476 495 524 549 573</td>
</tr>
<tr>
<td><strong>Total N uptake</strong></td>
<td>54 43 43 44 51 57</td>
<td>27 26 30 31 37 39</td>
</tr>
<tr>
<td><strong>Uptake from fertilizer</strong></td>
<td>0 2 3 4 7 9</td>
<td>0 1 3 4 7 8</td>
</tr>
<tr>
<td><strong>Uptake from soil</strong></td>
<td>54 41 40 40 44 48</td>
<td>27 25 27 27 31 31</td>
</tr>
</tbody>
</table>

Figure 2 The relationship between total available N (kg ha\(^{-1}\)) and N uptake in bulbs (kg ha\(^{-1}\)) at Réduit and Wooton in 2000.

\[
Y = 0.0456 X + 16.24 \quad r = 0.94 * \\
Y = 0.113 X - 26.37 \quad r = 0.33 \text{ NS}
\]

CONCLUSION

The results demonstrated that in all onion growing regions except Belle Mare/Palmar, the nutrient status of the soil were above optimal level. Under the range of conditions tested where the soil fertility was already high, the nutrient uptake in leaf was also optimal especially for N and P. Furthermore, the N uptake from the soil with increasing levels of N was lower than the unfertilized treatment. Hence, this study showed that there is effectively a need to optimize the fertilizer recommendation for onion in Mauritius.
ACKNOWLEDGMENTS

We are grateful to the staff of the Chemistry Division of the Ministry of Agriculture for chemical analysis of soil and plant nutrients. Thanks are also expressed to the Biometrician of AREU for data analysis.

REFERENCES


IMPROVEMENT OF SEED VIABILITY OF VEGETABLE SOYBEAN (GLYCINE MAX (L) MERRILL)

M Gungadurdoss
Agricultural Research and Extension Unit

ABSTRACT
Vegetable soybean (Glycine max (L) Merrill) is well adapted to our local agro-climatic conditions giving good yields of 11 – 15 t ha⁻¹ throughout the year. However, in Mauritius, a major constraint to its expansion is the rapid loss of seed viability which reflects the warm and humid ambient seed storage environments. To help growers keep their seeds at least until next planting, the efficacy in maintaining seed viability of 4 packagings namely unsealed polyethylene bag (100µ), sealed polyethylene bag, sealed bag made of aluminium foil and paper bag covered with sealed polyethylene bag at three different temperatures (ambient, 10°C, -10°C) was tested. Seeds with a moisture content of 9.6 % and a percentage germination of 100 were used for the study. Results showed that low temperature played a major role in maintaining viability of soybean seeds as about 90 % of seeds stored in any of the packagings at 10°C or -10°C were still viable after 14 months of storage compared to complete loss of viability after 6 to 10 months for ambient storage. The various packagings used were suitable for low storage temperatures as they maintained seed moisture content almost constant. For ambient storage, they still allowed an increase of 3 to 4.8 % in seed moisture content. Increase in seed moisture content contributed to rapid seed deterioration. Seed whose moisture content rose to 14.5 % when kept in unsealed polyethylene bag at ambient temperature showed complete loss of viability when field tested after 4 months. Seeds whose moisture content rose to about 12.6 % in sealed packaging at same ambient temperature lost viability only after 7 to 9 months.

Keywords: Soybean, seed longevity, temperature, packaging

INTRODUCTION
Research over the past years has shown that vegetable soybean is a crop, which is well adapted to our local agro-climatic conditions. It can be grown throughout the island and throughout the year giving yields of fresh pods ranging from 11 to 15 t ha⁻¹. Some 20 growers have already started the commercial cultivation of this newly introduced crop and to date about 2 to 4 hectares are being grown annually. Most of the growers who have adopted the crop are producing their own seeds which are not yet commercially available. Response in terms of consumer’s acceptance has also been positive because of the good taste and high nutritive value of vegetable soybean. However, in Mauritius, a major constraint to the expansion of tropical soybean production is poor stand establishment. Loss of seed viability during storage is a primary cause of that poor stand establishment and reflects the warm and humid ambient storage environments. In tropical areas, seed viability is often lost within 2 to 3 months after harvest (BR Gregg). This is attributed to the fact that soybean seeds are known to be inherently short lived because their seed coats readily permit entry of moisture and fungi which cause seed deterioration (SH West et al, 1984). This seed deterioration process is enhanced by high temperature and high humidity storage conditions that prevail in tropical climates like Mauritius. Though optimal storage conditions cannot stop deterioration, once started, it can still minimise it to maintain germination until planting (BR Gregg).

Thus, the main objective of this study was to identify a suitable, cheap and practical seed storage method which would enable farmers to maintain seed viability at least until next planting.
MATERIALS AND METHODS

In the study, which was carried out at the Réduit Crop Research Station, the efficacy in maintaining seed viability of 4 different packagings at 3 storage temperatures (ambient, 10ºC, -10ºC) was tested. The packagings used were as follows:

- P1: Unsealed polyethylene bag (100 µ)
- P2: Sealed polyethylene bag (100 µ)
- P3: Sealed bag made of aluminium foil
- P4: Paper bag covered with sealed polyethylene bag (100 µ)

Seeds with a moisture content of 9.6 % and a percentage germination of 100 were placed in the four different packagings and stored at the three different temperatures over a period of 14 months starting in April 2000 and ending in June 2001. Seeds stored in unsealed polyethylene bag at ambient temperature were used as the control.

Germination tests both in field and laboratory were conducted every month and were replicated three times for each storage treatment. The germination tests were set in a randomised complete block design.

In the laboratory 30 seeds from each treatment were placed on wet filter paper in petri dish for each replication. The filter paper was moistened with distilled water when necessary on alternate days. A seed was considered to have germinated when it produced a radicle of at least 1cm long within 10 days.

Germination tests in the field were conducted at Reduit Crop Research Station where 30 seeds of each storage treatment were sown in small plots under normal sowing practice. Watering of the plots was done once daily. A seed was considered to have germinated when the cotyledons emerged within 10 days. After 10 days from sowing, total germination counts were recorded both for laboratory and field.

Seed moisture content tests were conducted every two months. Five grams of seeds, replicated 3 times, for each storage treatment, were ground and used for determining moisture content using the oven method set at 103ºC for 17 hours.

RESULTS AND DISCUSSION

Effect of packaging on seed moisture content

For seeds kept at ambient temperature for the three types of sealed packaging (P2, P3, P4), an increase of about 3% in seed moisture content was observed (Table 1, Figure 1) after 14 months of storage. A greater increase of the order of 4.8 % was observed in the control (unsealed polyethylene bag) (Figure 1). At 10 and -10ºC, moisture content of seeds was kept almost constant (9.8 to10 %) irrespective of type of sealed packaging (Figure 1). However, in the unsealed polyethylene bag at 10ºC, a decrease of 1 % in moisture content was recorded (Figure 1). The relative humidity being low (30 %) at 10ºC, the seeds lost moisture to the air. Exchange of moisture with the air stops, only when equilibrium is reached. It has been reported by Delouche and Rodda (1976) that for seeds of moisture content of 9 to 10 %, the equilibrium is reached at about 60 % relative humidity. At -10ºC, seeds kept in the unsealed polyethylene bags showed a slight increase of 0.7 % in moisture content due to some ice particles which deposited on the seeds (Figure 1).

Effect of temperature on seed longevity

Low temperature played a major role in maintaining viability of vegetable soybean seeds. Viability of seeds, when tested in laboratory, was maintained up to 95 % after 14 months of storage for seeds kept at 10ºC and -10ºC irrespective of type of packaging (Table 2, Figure 2).

Seeds kept in sealed packaging (P2, P3 and P4) at ambient temperature lost complete viability after 9 to 10 months of storage (Figure 2). Similar results were obtained by Delouche (1974) who recommended that for a storage duration of about 9 months in tropical climates, seeds be dried to 9.3 % moisture content and stored in heat sealed polyethylene bags at ambient conditions. This loss of viability occurred earlier, that is after 7 months in the control (unsealed polyethylene bag at ambient temperature) (Figure 2).
### Table 1 Evolution of seed moisture content (%) over 14 months of seed storage

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<th>Pack</th>
<th>Temp °C</th>
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### Table 2 Percentage germination in laboratory after 14 months of seed storage

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### Table 3 Percentage germination in field after 14 months of seed storage

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Figure 1 Average seed moisture content (%)
Figure 2 Average percentage germination in laboratory

Storage Time (Months)

% Germination

Ambient Temperature

Temperature 10 °C

Temperature -10 °C

P1  P2  P3  P4
Figure 3 Average percentage germination in field

- Ambient Temperature
- Temperature 10 °C
- Temperature -10 °C

Storage Time (Months)

% Germination
Same trend was observed for germination in field. Viability of seeds was maintained at about 90% after 14 months of storage for seeds kept in sealed or unsealed packaging at 10°C and -10°C (Table 3, Figure 3).

At ambient temperature, viability was completely lost after 7 to 9 months of storage in sealed containers (P2, P3 and P4) while it was lost only after 4 months for seeds kept in unsealed polyethylene bag (Figure 3).

**Effect of seed moisture content on seed longevity**

Increase in seed moisture content contributed to the rapid loss of seed viability. This was shown by the complete loss of viability of seeds when field tested after 4 months for seeds whose moisture content rose to 14.5% when stored in unsealed polyethylene bag at ambient temperature (Figure 3). Seeds whose moisture content rose to about 12.6% in sealed packaging at same ambient temperature lost viability only after 7 to 9 months.

**CONCLUSION**

The study showed that low temperature played a major role in maintaining viability of vegetable soybean seeds and that storage at 10°C was as efficient as at -10°C. On the other hand, increase in seed moisture content contributed to a rapid decrease in seed longevity.

At 10 or -10°C, seeds with a moisture content of 9 to 10% can be stored safely for at least 14 months in any of the packagings used in the experiment. For ambient storage, higher density (~200 µ) sealed plastic bags should be used as the 3 sealed packagings tested still allowed an increase of 3% in seed moisture content. At AVRDC trials conducted revealed that at 8 to 10% seed moisture content, seeds stored in sealed high density plastic bags could maintain high seed viability for 2 years at 30°C if the seed lot had high initial seed viability (Ken-Feng Chen et al, 1991).

**ACKNOWLEDGEMENTS**

I would like to extend my thanks to the Director of AREU for his permission to publish the paper.

**REFERENCES**


GREGG BR. Soybean seed quality and practical storage. Mississippi State University, Mississippi State.

ABSTRACT

A survey on onion plantation carried out in two major growing areas of Mauritius viz: La Marie (122 ha) and Belle Mare (77 ha) in 1998 confirmed the prevalence of the Pink Root Rot disease (PRR) caused by Pyrenochaeta terrestris (Hansen). The exercise was extended in other traditional growing areas of Bamboo Virieux, Petit Sable and Grand Sable (7.2 ha) in 1999, revealing the widespread occurrence of the pink root rot disease in these regions also. Soil solarization with clear transparent polyethylene sheet of 40 microns for 4 and 6 weeks duration, and soil fumigation with dazomet @ 50 g m$^{-2}$ were evaluated for management of the disease in on-farm trials. Significant reduction in PRR and improvement in yield were obtained in onion with dazomet @ 50 g m$^{-2}$ and soil solarization for 4 and 6 weeks duration. Moreover, dazomet gave a better control than solarization.

Keywords onion, pink root rot, dazomet, solarization, Pyrenochaeta terrestris.

INTRODUCTION

On average, 10 000 tons of onions are produced annually in Mauritius amounting to about 55 percent of the local consumption. Many combined constraints lead to substantial variations in production levels and one among these is the prevalence of the pink root rot (PRR) disease. In Mauritius, the disease was first reported on onion in 1967 (ANON 1967) and eventually became widespread in all onion growing areas. The fungus attacks onion from seedling stage onwards with infected roots turning pink or reddish in colour. Diseased plants are easily pulled out. Above ground symptoms are stunting and yellowing, tip burn and die back of leaves. New roots become infected and are successively killed.

Field surveys on the distribution and incidence of the pink root rot disease in the regions of La Chaumière (1996), Belle Mare and La Marie (1998) revealed a high incidence of PRR disease at varying intensity and distribution in the regions (Maudarbaccus and Benimadhu, 1999). The exercise was repeated in the south east regions namely, Grand Sable, Petit Sable and Bambou Virieux in 1999.

This paper takes into account the survey carried out in 1999 in the regions of Grand Sable, Petit Sable and that of Bambou Virieux. It also reports on the on-farm evaluation trials involving fumigation with dazomet and soil solarization in selected fields known to be naturally infected with PRR at Belle Mare, La Chaumière and Grand Sable. The effects of the treatments on onion in terms of reduction of pink root rot infection and increase in yield were assessed and compared.

MATERIALS AND METHODS

Survey sites and sampling procedures

The sites surveyed and sampling procedures are presented in Table 1.

The three localities under study are situated in the south eastern coast of Mauritius with a total acreage of 7.20 hectares under onion cultivation. Soil at these sites is of alluvial origin (FAO / MSIRI, 1976) and the land is flat with slight undulation and fields are hand irrigated. The survey was conducted in September 1999 in the three localities having variety Local Red at 9-12 weeks stage.
Table 1 Profile of survey sites on onion at Petit Sable (PS), Grand Sable (GS) and Bambou Virieux (BV) September 1999

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<th>Site</th>
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<th>Samples collected</th>
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<tr>
<td>GS</td>
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<td>BV</td>
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Sampling

The sampling area surveyed in September 1999 covered a total area of 2.77 ha for the three regions. In all, 23 fields were surveyed and 345 samples collected and examined from the three regions altogether. Onion samples were collected from the three sites when the crop stand was at 9 to 12 weeks after transplantation in systematically selected fields. From each field surveyed, 15 random plants were carefully uprooted by means of a dibble, labelled and taken to the laboratory for pink root assessment. The root system of each plant was carefully washed in slow running water and visually examined for any typical pink discolouration. A plant with at least one root showing pink discolouration was considered as infected. The number of infected roots and the total number of roots of each plant sampled were noted and the percentage root infection calculated to indicate infection levels.

Soil fumigation and Soil solarization

Fumigation with Basamid

Basamid, a granular soil fumigant (98% dazomet), was spread @ 50 g / m² at all the trial sites. It was incorporated in the soil by light hand hoeing which was compacted to prevent gas loss and kept moist for one week. The compacted soil was loosened a week after treatment and onion transplantation effected two weeks after soil loosening at all sites.

Solarization

Solarization was achieved by laying clear transparent UV-treated polyethylene plastic sheet of 40 microns thickness to cover well irrigated soil and kept in position for 4 and 6 weeks duration at all sites. Onion seedlings were transplanted at each site after the expiry of 4 and 6 weeks solarization period.

Plot establishment

On-farms trials were set up in the onion growing localities of Belle Mare (BM) (June 01), La Chaumière (LC) (July 01) and Grand Sable (GS) (July 01) for fumigation with fumigant dazomet (D) and soil solarization (S) for a period of 4 (S4) and 6 (S6) weeks duration. Table 2 shows characteristics of the trials.

Experimental design and treatments

Treatments consisted of three transplanted plots with five replicates for each trial at each location with plot size of 15 m². A random complete block design was used. Fumigant Basamid (98% dazomet) was applied at the rate of 50 g / m² to the soil surface and incorporated to a depth of approximately 15 cm. Onion seedlings were transplanted three weeks after the treatment. Clear transparent polyethylene plastic sheet of 40 microns was laid on wetted soil for a period of 4 and 6 weeks duration respectively. Onion seedlings were then transplanted after expiry of the solarization period of 4 and 6 weeks on dates as indicated in Table 2.

Seedlings obtained from dazomet treated nurseries were transplanted to treated plot (T x T) and to untreated plot (T x UT) while untreated seedlings obtained from untreated nurseries were transplanted to untreated plot (UT x UT). Likewise seedlings obtained from solarized beds were transplanted to


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solarized (S x S) and to non-solarized plots (S x NS) while non-solarized seedlings were transplanted to non-solarized plots (NS x NS) of 4 and 6 weeks duration. Standard cultural practices as given in the Guide Agricole 98- Cultures Légumières (1998) were employed throughout the crop cycle.

**Table 2** Characteristics of trials at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS)

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Soil</th>
<th>Area seed bed for each treatment m²</th>
<th>Date main field treated</th>
<th>Duration of solarization Weeks</th>
<th>Date transplanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM</td>
<td>Local Red</td>
<td>Sandy *LRP to Regosol</td>
<td>7</td>
<td>3-May-01</td>
<td>S6</td>
<td>4-Jun-01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17-May-01</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>LC</td>
<td>Véronique</td>
<td>Heavy ** DMC</td>
<td>9</td>
<td>23-Jun-01</td>
<td>S4</td>
<td>11-Jul-01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S6</td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>Local Red</td>
<td>Alluvial</td>
<td>10</td>
<td>14-Jun-01</td>
<td>S4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S6</td>
<td></td>
</tr>
</tbody>
</table>
*LRP: Latosolic Reddish Prairie **DMC: Dark Magnesium clay.

All plots were assessed at three stages of the crop cycle viz; 9, 11 and 13 weeks after transplanting which corresponded to bulb initiation, bulb development and bulb maturation stages except for Belle Mare where assessment at harvest (13 weeks) could not be performed as the grower harvested his crop at an earlier stage. Disease assessment was performed as described under section “sampling”. Counts were made in terms of total number of roots, number of infected roots and yield was recorded.

**RESULTS AND DISCUSSION**

**Survey**

Figures 1 and 2 show results obtained for the survey for the regions of Grand Sable, Petit Sable and Bambou Virieux in terms of incidence and distribution of the pink root rot disease. Prevalence of the PRR pathogens is confirmed in the three regions at varying levels with Grand Sable showing highest infection of 55.4% followed by Petit Sable 51% and that of Bambou Virieux 38.3 percent respectively.

Figure 2 shows the distribution of infection in the three regions of Petit Sable (PS), Grand Sable (GS) and Bambou Virieux (BV). The range of infection in the three localities shows variation from a minimum level of infected plants of 5% at Bambou Virieux to a maximum of 46% of plants showing root infection in Bambou Virieux. A larger number of plants tend to fall in higher infection ranges at Grand Sable and Petit Sable in contrast to plants in Bambou Virieux. This could be explained by the fact that the two localities have a longer history of onion production and was previously known to be the granary for onion in Mauritius. Another explanation is the continuous cropping of susceptible Local Red onion on the same land without crop rotation or any other disease management.

**Soil fumigation with dazomet and soil solarization**

The effects of fumigation with dazomet and that of soil solarization were assessed at harvest with all sampled bulbs, checked for disease expression and weight, results of which are shown in Table 3.
Figure 1 Incidence of PRR disease in Petit Sable, Grand Sable and Bamboo Virieux.

Figure 2 Distribution of PRR infection at Petit Sable, Grand Sable and Bamboo Virieux.
Table 3 Effects of dazomet and soil solarization at harvest on PRR expression and fresh yields of onion at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS).

<table>
<thead>
<tr>
<th>Site</th>
<th>Dazomet treated plots</th>
<th>Solarization S4</th>
<th>Solarization S6</th>
<th>Untreated plots (Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infection %</td>
<td>Yield t ha⁻¹</td>
<td>Increased Yield %</td>
<td>Infection</td>
</tr>
<tr>
<td>BM</td>
<td>12.4</td>
<td>17.3</td>
<td>35.2</td>
<td>36.4</td>
</tr>
<tr>
<td>LC</td>
<td>17.4</td>
<td>34.0</td>
<td>40.2</td>
<td>15.0</td>
</tr>
<tr>
<td>GS</td>
<td>17.9</td>
<td>10.0</td>
<td>34.0</td>
<td>39.2</td>
</tr>
</tbody>
</table>

Soil temperatures

In the solarized plots at Belle Mare, La Chaumière and Grand Sable, soil temperatures varied between 37 °C and 42 °C compared to temperatures in non-solarized plots varying between 25 °C and 30 °C.

Table 4 Mean soil temperatures (°C) in solarized and non-solarized plots at 10 cm depth

<table>
<thead>
<tr>
<th>Solarization</th>
<th>Belle Mare</th>
<th>La Chaumière</th>
<th>Grand Sable</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4</td>
<td>42</td>
<td>38</td>
<td>41</td>
</tr>
<tr>
<td>S6</td>
<td>40</td>
<td>37</td>
<td>39</td>
</tr>
<tr>
<td>Non-solarized</td>
<td>29</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

Significant increase in soil temperatures lowered infection percentage in solarized plots which can be attributed to the thermal sensitivity of the PRR pathogen *Pyrenochaeta terrestris*.

Associated side-effects

Besides reducing incidence of the PRR disease, fumigation and solarization offered good control of damping off at nursery level, and also good weed control in all treated plots. Untreated plots and the immediate surrounding land required 2 to 3 hand weeding rounds, with predominating weeds like Portulaca, Amaranthus and several annual grasses. Increased onion vigour was also evident throughout the growing seasons in treated plots.

Infection dynamics

The kinetics of infection in the soil fumigation and solarization plots conducted at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS) are presented in Figure 3 indicating disease development at 9, 11 and 13 weeks after transplantation in both treated (fumigated and solarized) and untreated plots (non fumigated and non solarized).

Disease assessment at 9, 11 and 13 weeks after transplanting showed that dazomet significantly reduced pink root rot expression when compared to solarization. A pink root rot infection of 12.4 % at Belle Mare, 17.4 % at La Chaumière and 17.9 % at Grand Sable was obtained with dazomet at harvest in contrast with solarization at 4 weeks (S4) and 6 weeks (S6) with infection percentage of 36.4, 15.0, 39.2 and 34.5, 16.6 and 39.0 respectively. Dazomet proved more efficient in reducing incidence of the disease. However both treatments did not ensure eradication of the pathogen, attributed mainly to the very high infection potential of the soil.
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**Figure 3** Kinetics of PRR infection at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS).

![Graph showing kinetics of PRR infection](image)

Yield of fresh bulbs

**Figure 4** shows the effects of dazomet and solarization on yield at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS).

Significantly higher yield was obtained in dazomet fumigated and solarized plots compared to control plots. The total fresh bulb yield obtained in dazomet fumigated plots was higher than that obtained in solarization S4 and S6 plots, with incremental gains of 35.2% at Belle Mare, 40.2% at La Chaumière and 34% at Grand Sable.

**DISCUSSION**

Fields in onion growing areas in the South East region of Mauritius, namely Petit Sable, Grand Sable and Bambou Virieux are infected with the pink root rot pathogen. Previous studies also revealed the widespread occurrence of the pathogen in other major onion growing areas in the West, the Central Highland and the East of the island (**Figure 5**).

Continuous cropping with onion on the same land in the above regions for years, (around 100 years for Grand Sable) has produced a downside by way of increased disease pressure due to the soil borne pink root-rot pathogen, *Pyrenochaeta terrestris* (Hansen), resulting in economic losses.

Management of the disease has so far proved difficult for various reasons. In practice, land being scarce, growers continuously cultivate onion in the same field till no crop can be produced due to increase in soil inoculum levels of the PRR pathogen. Moreover, the pink root rot pathogen is known to persist in fields for many years, limiting the efficacy of crop rotations, and locally commercialized PRR resistant onion varieties have not performed as expected in terms of resistance to the disease probably due to the existence of different physiological races of the fungus locally.
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**Figure 4** Yield of fresh bulbs at Belle Mare (BM), La Chaumière (LC) and Grand Sable (GS) at harvest.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>BM 11</th>
<th>LC 13</th>
<th>GS 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>25</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>S4</td>
<td>20</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>S6</td>
<td>15</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Figure 5** Pink root disease in major onion growing areas of Mauritius

Our research, however, clearly indicates possibilities for reducing inoculum level in the field with soil fumigation and soil solarization. These treatments significantly reduced incidence of the disease...
without however not eliminating the pathogen from the soil altogether. Welcome side effects associated with the treatments were reflected in the yield of fresh bulbs, and in the excellent weed control in treated plots whereas several rounds of hand weeding were necessary in untreated plots. On the same line damping off disease due to certain soil borne pathogens like Phytophthora and Fusarium spp was virtually absent in treated seed beds compared to untreated ones in nurseries. The treatments also conferred increase in yield ranging between 17.5 and 40.2 %. These positive effects are not expected to be restricted to the first crop following treatment but, as reported in similar studies (Neuman, 1983), they may be carried over into subsequent crops.

In our study, fumigation achieved better control and higher increase in yield of 40.2 %. Soil solarization, a process that employs solar radiation, may however provide a safer management tool, being a non-chemical and environmental-friendly method. The climate in summer in the onion growing areas (with perhaps the exception of La Marie) makes them amenable to soil solarization. Temperatures achieved in solarized plots in this study are comparable to those reported to be effective for controlling soil borne pathogens (Garibaldi and Tamietti, 1989). Soil solarization can thus be a particular attractive tool for the management of the pink root rot disease.

CONCLUSION

Pink root rot disease due to fungal pathogen Pyrenochaeta terrestris (Hansen) is prevalent in onion growing areas in the South East of Mauritius namely Petit Sable, Grand Sable and Bambou Virieux. Previous studies have also confirmed the widespread occurrence of the disease in other traditional onion growing areas like La Marie, Belle Mare and La Chaumière. The pink root rot disease is thus a serious handicap in onion production in all major onion growing areas of Mauritius.

On-farm trials have shown that soil fumigation and soil solarization provide a significant reduction in disease incidence resulting in increase in yield between 17.5 to 40.2 %. The prospect of combining soil treatments (fumigation and solarization) with good agricultural practices and sanitation in an integrated approach for a proper management package needs to be further investigated.

ACKNOWLEDGEMENTS

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REARING OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (L.) (LEPIDOPTERA:YPONOMEUTIDAE) ON ARTIFICIAL DIET IN THE LABORATORY

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Agricultural Research and Extension Unit

**ABSTRACT**

A technique to rear *Plutella xylostella* (L) on artificial diet was developed in the laboratory. The suitability of four types of diets (Biever’s, G*, G** and soya diets) was tested. Soya diet was found to be the most suitable one. The life cycle from egg to adult lasts 18 days at 26 ± 2°C and 60 – 65% RH. Caged moths lived for about 11 days. A mated female (reared on soya diet) laid an average of 207 eggs during her lifetime. The majority of eggs were collected during the first 5 days. Grooved aluminium foil dipped in fresh cabbage juice was found to be a suitable oviposition substrate for egg collection. Eggs seeded on diet hatched within 3 days. Larval development (1st to 4th instar) was completed in 10-11 days and the pupal period was 3-4 days.

**Keywords**: *Plutella xylostella*, soya diet, egg, adult and aluminium foil

**INTRODUCTION**

The diamondback moth (DBM), *Plutella xylostella*, is a major pest of cabbage and cauliflower in Mauritius. The pest was controlled easily with insecticides until 1980 when severe failures of pesticides began to occur and progressively growers reported resistance problems (Dunhawoor et al. 1997). As an alternative to pesticides, *P. xylostella* was then considered for control by F1 sterility technique in conjunction with biological and cultural methods. F1 sterility technique has been considered as an advantageous genetic method for suppression of lepidopteran populations by introducing lethal mutations in reared moths and releasing them into wild populations which ultimately decreases fertility in F generations (Knipping and Klassen 1976, La Chance 1984, Mastro and Schwalbe 1988, Omar et al. 1993). To implement this technique, mass rearing of *P. xylostella* is required for releases of large numbers of irradiated moths. The technique for rearing DBM on artificial diet has been developed by Biever et al. (1971), Koshihara (1976) and Hsiao et al. (1978). *Plutella xylostella* was first reared on cabbage plants. This method was abandoned because it required large quantities of cabbage plants and many cages. Rearing of *P. xylostella* on artificial diet was thus initiated in 1998. A colony was established from field collected larvae and pupae but was destroyed after 4 months because of infection with a microsporidian pathogen (*Nosema* spp.). Microbial contamination is one of the major problems affecting the rearing of insects (Sikorowski et al. 1994). The paper reports on procedures for:

1. establishment of a disease free colony in greenhouse and laboratory
2. selection of a suitable artificial diet
3. fecundity and longevity of moths raised on diets and
4. development time and method to maximise egg collection in laboratory.

**MATERIALS AND METHODS**

**Establishment of a disease free colony**

An effective sanitation programme was set-up and included frequent cleaning of laboratory and disinfecting of walls, shelves, floor and insectary equipment with a detergent sanitiser (ANTEC DSC-1000) and was maintained to keep a clean environment for the rearing programme.
Rearing of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: yponomeutidae) on artificial diet in laboratory.

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DBM larvae and pupae were collected from isolated sites (Plaine Sophie, Henrietta, Palma, Midlands, La Chartreuse, Providence, L’Escalier, Belle-Vue and Terre Rouge) and reared on cabbage leaves in separate cages in the greenhouse. Moths were dissected and those from Henrietta, Palma, Midlands and Belle-Vue were found free from disease. Males and females from 10 cages from the above mentioned sites were allowed to mate and single pair colonies were set. They were reared for 10 generations. At each generation, 25 adults were randomly selected and were dissected to check the presence of microsporidian spores. The adults were found free from spores.

The individual colonies from the 4 sites were then mixed to form a single colony. This greenhouse colony generated eggs for the establishment of DBM colony on artificial diet. Eggs were first surface sterilised (dipped in 12 % of sodium hypochlorite solution), washed with distilled water and dried under a Laminar flow with HEPA filters.

**Selection of a suitable diet for rearing DBM larvae**

13 types of diets were initially tested in the laboratory. Four promising diets, Biever’s, G, G+ and soya diets, were retained for further studies in the selection of a suitable one for DBM rearing.

The 4 diets (Biever’s, G, G++ and soya) were prepared using ingredients given in Table 1. The diets were cut into cubes (1x 1 x 1cm) and 2 cubes of each diet were placed in a solo plastic cup under a Laminar flow to avoid mould contamination. Four sets of cups with diets were prepared.

Greenhouse eggs were surface sterilized and kept at 22 ± 2°C in an incubator for 48 hours. 250 newly hatched larvae (<24 hr) were selected. 10 individuals were placed in a cup with each type of diet. As control, 10 larvae were placed in a cup with cabbage leaves. The experiment was conducted in 5 replicates.

All cups were placed in the larval rearing room at 26 ± 2°C and 60 –  65% RH. A diet cube was added at 8 day-intervals and cabbage leaves in the control cup every 2 days.

The number of pupae from each type of diet was recorded and kept separately in cages. Emerging moths were weighed and number of emergences was also recorded.

**Longevity and fecundity of *Plutella xylostella***

DBM larvae reared on Biever’s, G, G++ and soya diets and cabbage leaves were kept separately until pupation. Collected pupae were kept in individual gelatin capsules. Newly emerged males and females (1day old) were allowed to mate.

Five pairs of moths (mated female and male) from each diet and cabbage were placed in 5 solo plastic cups (4 x 4 cm in size) and fed with 20 % honey solution. A grooved aluminium foil (2 x 1.5 cm in size) dipped in boiled cabbage juice was placed in each cage to collect eggs. Aluminium eggsheets were replaced daily and eggs on sheets and on the interior of cages were counted. Male and female longevity was also recorded.

**Development Time**

5 sets of eggs (300/set) from mated females (reared on soya diet) were surface sterilized and seeded in plastic cups with 100 mL of soya diet. The cups were examined every 24 hr to determine the time when eggs hatched and the development time from 1st instar larva to pupal stage.

**Oviposition Substrate**

Six types of substrates used as eggsheets (kitchen towel, plain aluminium foil, crinkled aluminium foil, grooved aluminium foil, grooved aluminium foil soaked in fresh cabbage juice and grooved aluminium foil soaked in boiled cabbage juice) were tested as eggsheets for egg deposition from cages. Each substrate measured 8 x 7.5 cm in size.

100 males & 100 females were placed in a cage (6x 6 cm) and fed with 10 % honey solution. 6 such cages were set up and one type of substrate (2 foils) was placed in each of them. The experiment was replicated three times.

Eggsheets from each cage were collected every 24 hours for two consecutive days and eggs counted.
RESULTS

Selection of a suitable diet for rearing DBM larvae

An average of 75% of the greenhouse larvae reared on cabbage attained pupal stage. Among the diets, pupal yield from soya diet was highest (52%). The percentage of pupal harvest on Biever’s, G* and G** diets were 44%, 34% and 46% respectively (Table 2).

Moth emergence from larvae on cabbage and soya diet was 54% and 42% respectively. The percentage of moth emergence from Biever’s, G* , G** diets ranged from 20% to 28%. The number of males emerging from Biever’s, G* and G** diets was higher whereas the number of females from soya diet was higher.

The weight of females was significantly higher than that of males irrespective of diets. However, the mean weight of female reared on soya diet was significantly higher (0.0056 g) than those raised on other diets.

Table 1 List of ingredients required to prepare 1 Litre of diet

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Biever’s diet</th>
<th>G*</th>
<th>G**</th>
<th>Soya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agar</td>
<td>g 24.0</td>
<td>22.5</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Alphacel</td>
<td>g 6.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>g 4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Aureomycin</td>
<td>g 1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Brewer’s yeast</td>
<td>g 16.2</td>
<td></td>
<td>16.2</td>
<td></td>
</tr>
<tr>
<td>Cabbage powder</td>
<td>g 30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Casein</td>
<td>g 32.0</td>
<td>35.0</td>
<td>35.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>g 2.5</td>
<td></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Choline chloride</td>
<td>g 1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>L. Inositol</td>
<td>g 0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>Methyl P **</td>
<td>g 1.4</td>
<td>2.0</td>
<td>2.0</td>
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</tr>
<tr>
<td>Potassium sorbate *</td>
<td>g 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>g 2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Soya flour</td>
<td>g 34.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Sucrose</td>
<td>g 34.0</td>
<td>35.0</td>
<td>35.0</td>
<td>35.0</td>
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<tr>
<td>USDA vitamin premix</td>
<td>g 10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Wesson salts</td>
<td>g 9.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Wheat germ raw</td>
<td>g 44.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KOH solution</td>
<td>ml 5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Linseed oil (raw)</td>
<td>ml 6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soya oil</td>
<td>ml 7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Triton x solution</td>
<td>ml 10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Water</td>
<td>ml 750.0</td>
<td>840.0</td>
<td>840.0</td>
<td>840.0</td>
</tr>
</tbody>
</table>

* Dissolved in 15 mL of water  ** Dissolved in 15 mL of alcohol
Rearing of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: yponomeutidae) on artificial diet in laboratory.

*C Dunhawoor and D Abeeluck


### Procedure for preparing diet:

1. Weigh ingredients separately.
2. Mix dry ingredients, soya oil, KOH and Triton-x solutions in 220 mL of hot water (70°C) in a blender.
3. Dissolve agar in 620 mL of water in a cooking pot at 80°C
4. Cool dissolved agar to 70°C and pour it in the blender containing the mixed ingredients.
5. Ground thoroughly the mixture for 1-3 minutes
6. Dispense the hot diet in cups
7. Scarify’ the top of the diet (when cooled) with a scarification tool.
8. Store the cups with diet in plastic bags in refrigerator

### Table 2 Percentage pupal harvest and moth emergence and mean weight of moths from greenhouse larvae reared on different types of diet

<table>
<thead>
<tr>
<th>Diet</th>
<th>Pupal Harvest (%)</th>
<th>Moth Emergence (%)</th>
<th>Sex Ratio (M:F)</th>
<th>Mean Weight of Moth (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>male</td>
</tr>
<tr>
<td>Cabbage</td>
<td>75</td>
<td>54</td>
<td>1:1</td>
<td>0.0027</td>
</tr>
<tr>
<td>Biever's diet</td>
<td>44</td>
<td>26</td>
<td>2:1</td>
<td>0.0026</td>
</tr>
<tr>
<td>G'</td>
<td>34</td>
<td>20</td>
<td>3:2</td>
<td>0.0024</td>
</tr>
<tr>
<td>G''</td>
<td>46</td>
<td>28</td>
<td>2:1</td>
<td>0.0028</td>
</tr>
<tr>
<td>Soya</td>
<td>52</td>
<td>42</td>
<td>2:3</td>
<td>0.0044</td>
</tr>
</tbody>
</table>

### Longevity and fecundity of *Plutella xylostella*

Adult longevity of DBM males and females reared from the 5 types of diets are shown in Figure 2. Males reared from all diets lived longer (11 – 13 days) compared to females (8 – 11 days). On soya diet, females lived for about 9 days.

All mated females produced eggs for 9 days. Egg laying started 24 hours after mating. Data on the cumulative number of eggs laid by females reared on the 5 diets are represented in Figure 1. The average number of eggs per female reared on cabbage leaves during her life time was 225. A female (from soya diet) laid 207 eggs whereas those reared from Biever’s, G', and G'' diets laid 103, 163 and 135 eggs respectively. About 78 % of the eggs were collected during the first 5 days.

The average number of eggs per female raised on soya diet or cabbage was similar and was significantly higher than the number per female raised on the other 3 diets (P < 0.05).

### Development Time

Hatching of eggs started after 48 hours of incubation. Larval development (1st to 4th instar) was completed in 10-11 days and the pupal period was 3-4 days.

### Oviposition substrate

Among the 6 types of substrates, the number of eggs recorded on aluminium foil dipped in boiled cabbage juice was significantly higher (Table 3). Egg numbers on aluminium foil dipped in boiled cabbage juice was 12 times higher than aluminium foil dipped in fresh cabbage juice.
Rearing of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: yponomeutidae) on artificial diet in laboratory.
*C Dunhawoor and D Abeeluck*

**Figure 1** Cumulative numbers of eggs laid by females reared on different diets

**Figure 2** Male and Female longevity of DBM moths reared on artificial diet.
Table 3

<table>
<thead>
<tr>
<th>Oviposition Surface</th>
<th>Egg count</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towel Paper</td>
<td>1 806</td>
<td>602 b</td>
</tr>
<tr>
<td>Aluminium foil plain</td>
<td>4 437</td>
<td>1 479 b</td>
</tr>
<tr>
<td>Aluminium foil crinkled</td>
<td>2 075</td>
<td>692 b</td>
</tr>
<tr>
<td>Aluminium foil grooved</td>
<td>2 985</td>
<td>995 b</td>
</tr>
<tr>
<td>Aluminium foil grooved + fresh cabbage juice</td>
<td>938</td>
<td>312.7 c</td>
</tr>
<tr>
<td>Aluminium foil grooved + boiled cabbage juice</td>
<td>11 154</td>
<td>3 718 a</td>
</tr>
</tbody>
</table>

Numbers within a column with the same letter are not significantly different (P < 0.05)

DISCUSSION

Soya diet was the most suitable one for DBM rearing. In addition to the basic ingredients in Biever’s diet, Brewer’s yeast, Sorbic acid, Cholesterol, L. Inositol, Choline Chloride and Triton - x solution were incorporated in soya diet (Table 1). The poor larval development on Biever’s diet could be related to the absence of Cholesterol that is essential for successful insect molting and wing formation (Chapman, 1991 and Inositol, a phagostimulant (Hsiao & Hou, 1978). Sorbic acid controls microbial contamination (Carpenter et al. 20002). DBM larval development period on soya diet was almost similar to that on cabbage (10-11 days).

DBM can be successfully reared on soya diet with strict sanitary measures in the rearing facility. Occasional contamination (microbial and mould) is almost inevitable and can cause high mortality in DBM larvae and adults. This can be suppressed by maintaining a clean environment and sterilising laboratory equipment, eggs and diets.

It is now desirable to determine whether there is any change in the biological performance of these laboratory reared moths.

ACKNOWLEDGEMENTS

We are grateful to the staff of the Entomology Division and Mr R.K. Ramnauth (Biometrician) for their assistance.

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Rearing of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Yponomeutidae) on artificial diet in laboratory. 
*C Dunhawoor and D Abeeluck*


DEVELOPPEMENT ET OPTIMISATION D’ATTRACTIFS ALIMENTAIRES POUR LA MOUCHE DU MELON BACTROCERA CUCURBITAE (COQUILLETT) (DIPTERA: TEPHRITIDAE)

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RESUME
Nous avons testé l’attractivité relative de cinq levures (deux levures de Torula, levure de boulangerie, déchet de brasserie et levure de bière) vis-à-vis de la mouche du melon Bactrocera cucurbitae (Coquillett) par une méthode de lâchers-recaptures en cages extérieures. En outre, nous avons étudié l’effet de l’ajout de borax et de variations de pH sur l’attractivité de deux hydrolysats de protéine commercialisés, le Nulure® et le Buminal®, de la levure de boulangerie, de la levure de Torula et du déchet de brasserie.
La levure de Torula, la levure de boulangerie et le déchet de brasserie ont une attractivité deux fois supérieure à celle du Buminal, seul hydrolysat actuellement homologué en France. L’acidification du Buminal à pH 3, l’alcalinisation de la levure de boulangerie à pH 6 ou de la levure de Torula à pH 10,5 augmentent leur attractivité par rapport à celle des solutions au pH initial (respectivement pH 6, 5 et 9). Cependant, toute acidification ou alcalinisation supérieure diminue cette attractivité. L’ajout de borax diminue l’attractivité des hydrolysats.
Ces résultats s’avèrent utiles pour le choix d’attractifs efficaces pour la surveillance ou le contrôle de Bactrocera cucurbitae et sont susceptibles d’applications en termes de piégeage ou de traitement par taches.

Mots-clés: Attractif alimentaire, Bactrocera cucurbitae, piégeage, Saccharomyces cerevisiae, Candida utilis, pH, borax.

INTRODUCTION
Les Dacinae forment une sous famille d’une importance économique considérable au sein de la famille des Tephritidae. Cinq espèces sont présentes à la Réunion, dont 3 qui attaquent les Cucurbitaceae. Malgré les traitements phytosanitaires régulièrement appliqués contre elles, elles constituent le principal problème entomologique sur ces cultures maraîchères (Vayssières and Carel 1999). Les dommages les plus importants (jusqu’à 100 % de la production dans les parcelles non traitées) sont causés par la mouche du melon Bactrocera cucurbitae (Coquillett), qui attaque à La Réunion 12 espèces de Cucurbitaceae cultivées (Étienne 1972, Vayssières and Carel 1999).

Le contrôle de ces ravageurs passe actuellement par un épandage systématique de pesticides à large spectre, entraînant l’habituel cortège de problèmes écologiques et sanitaires. Dans ce domaine, la priorité est par conséquent de développer une technique de traitements par taches et donc de sélectionner un attractif alimentaire adapté.

Comme celles de nombreuses Tephritidae, les femelles de B. cucurbitae ont besoin d’un apport protéique pour compléter leur maturation sexuelle et permettre le développement ovarien (Hagen and Finney 1950). Les attractifs alimentaires classiquement utilisés consistent donc en produits dérivés d’hydrolysats ou autolyssats de protéines issues de levures, de soja ou encore de soja (Fabre et al. 2003).

Depuis fin 2000, le CIRAD Réunion travaille à la comparaison de différents attractifs commercialisés, à la recherche de nouvelles sources d’appâts protéiques et à l’optimisation de ces différents appâts. Les résultats obtenus sur la comparaison d’hydrolysats de protéines ont montré que le Buminal®


**MATERIEL ET MÉTHODES**

**Élevage**

L’élevage de *B. cucurbitae* provient de pupes collectées en juin 2000 sur citrouilles infestées (*Cucurbita maxima* Duchesne) en trois localités de basse altitude de la Réunion (Petite Ile, Bassin Martin et Piton Saint Leu). Les adultes sont élevés en conditions contrôlées (25 ± 2°C, 70 ± 20 HR et LD 12:12). Ils sont nourris avec un mélange de sucre et d’hydrolysat de levure (ICN Biomedicals, Aurora, OH, USA) et ont accès en permanence à une source d’eau.

Trois fois par semaine, on introduit dans la cage pendant une heure 2 courgettes (*Cucurbita pepo* L.) qui constituent un substrat de ponte. Les larves sont ensuite nourries avec de la citrouille et de la pomme de terre déshydratée, puis les pupes sont récoltées par tamisage et mises en étuve à 25°C jusqu’à l’émergence. La nouvelle cohorte d’adultes est alors isolée en cage de 40 x 40 x 40 cm et est ultérieurement utilisée pour les essais lorsque les adultes atteignent entre 15 à 25 jours après l’émergence, âge qui correspond à la maturité sexuelle optimale (Vargas et al. 1984).

**Dispositif expérimental**

Les essais se déroulent en extérieur à la station expérimentale de Bassin Plat (Saint Pierre), en cages de mousseline cylindriques de 2,5 m de haut pour 3 m de diamètre (amber HDPE screen cage, Synthetic Industries, Gainesville, USA). Nous disposons une vingtaine de plants de giraumon (*Cucurbita moschata* Duchesne, var. Martinica, Technisem, France) au centre de chaque cage afin de recréer un milieu semi naturel. 250 mouches de même sexe sont lâchées dans chaque cage une demi heure avant d’y installer les attractifs. Ceux-ci sont placés dans des pièges de type Mc Phail (Dome Trap, Agrisense, Pontypridd, U.K.) dont la partie inférieure a été peinte en noir afin de limiter l’influence des stimuli visuels. Les pièges sont accrochés à une potence à 50 cm du sol, sur un cercle imaginaire de 1 m de diamètre. On place quatre pièges par cage, en plus du témoin placé au centre de la cage et rempli d’eau. La position initiale de chacun des 4 pièges est aléatoire, puis ils sont déplacés de 90° toutes les deux heures pendant les 8 heures de l’essai afin de supprimer un éventuel effet d’emplacement. Chaque essai est répété 4 fois pour chacun des deux sexes.

**Essais**

**Comparaison d’attractifs à base de levures**

Nous avons étudié l’attractivité de 5 levures ou dérivés de levures : le déchet de brasserie frais (*Saccharomyces cerevisiae* Meyen *ex* E.C. Hansen, Brasseries de Bourbon, La Réunion), la levure de bière séchée (*S. cerevisiae*, Cereal, France), la levure de boulangerie déshydratée (*S. cerevisiae*, Instant Success, Reudis, La Reunion) et deux levures de Torula (*Candida utilis* Henneberg), Agrisense, UK et Attisholz, Suisse). Ces deux types de levures de Torula seront ultérieurement désignées Torula US et Torula Suisse. La levure de Torula US est en fait un mélange compacté de levure et de borax ou de sodium tétraborate.

Chacun de ces produits a été comparé au Buminal, hydrolysat de protéine de référence dilué, à 10%. Les concentrations utilisées sont de : Torula Suisse 20 g L⁻¹, Torula US 45 g L⁻¹, levure de boulangerie 20 g L⁻¹, levure de bière séchée 20 g L⁻¹. Le déchet de brasserie est chauffé à 100° C jusqu’aux

premiers signes d’ébullition afin déliminer un maximum d’alcool, puis refroidit doucement à température ambiante et dilué à 50% (teneur finale en matière sèche 8-15 %).

**Optimisation des attractifs**

Nous avons observé l’effet de la variation du pH sur le Buminal à 5 % (pH initial 6), la levure de Torula US (45 g L⁻¹, pH initial 10.5), la levure de boulangerie (20 g L⁻¹, pH initial 5) et le déchet de brasserie à 50 % (pH initial 5.5). Ces produits ont été acidifiés par ajout d’acide chlorhydrique ou alcalinisés par ajout d’hydroxyde de sodium. On compare ensuite chacun à 4 pH différents. Dans le cas de la levure de boulangerie et du déchet de brasserie, le pH des solutions testées a été contrôlé en fin d’essai.

Nous avons ensuite étudié l’effet de l’ajout de borax sur l’attractivité du Nulure® (Miller Chemicals & Fertilizer Corporation, Hanover, U.S.A.) à 5 % et du Buminal à 5 %. Deux expériences ont été menées: dans la première nous avons comparé du Buminal à 0, 1, 5 et 10 % de borax, dans la deuxième du Nulure auquel nous avons adjoint les mêmes concentrations de borax. Le borax est dissous dans l’eau bouillante et mélangé à l’hydrolysat après refroidissement à l’air libre.

**Analyse statistique**

Pour comparer l’attractivité relative de chaque produit, nous avons pour chaque cage calculé le pourcentage de mouches capturées par piège par rapport au nombre total de mouches capturées. Ces pourcentages ont été transformé par arcsin v x pour stabiliser la variance, puis analysés par ANOVA à trois facteurs avec interaction du premier ordre (Statistica 99, Statsoft). Trois facteurs sont étudiés: produit (5 niveaux), sexe (2 niveaux) et jour (2 niveaux). En cas de F significatif (p<0,05), nous utilisons un test de Tuckey de comparaison de moyennes.

**RESULTATS**

**Comparaison d’attractifs à base de levures**

Les résultats de toutes les expériences effectuées ne montrent aucune influence des facteurs «sexe» et «jour». Nous ne prendrons donc en considération que le facteur «produit».

Dans le protocole utilisé, la confrontation directe de deux produits de type «levure» permet difficilement de mettre en évidence une différence d’attractivité (données non publiées). Pour les discriminer, nous avons donc établi pour chacun de ces produits un coefficient d’attractivité par rapport au Buminal (Tableau 1).

**Tableau 1** Attractivité relative comparées des différentes levures testées par rapport au Buminal. Les lettres correspondent à des groupes de moyennes distinctes.

<table>
<thead>
<tr>
<th>Type de levure</th>
<th>% moyens d’attractivité</th>
<th>Nombre de captures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Témoin - Buminal - «Levure»</td>
<td></td>
</tr>
<tr>
<td>Levure de Torula US</td>
<td>4.39 a - 30.4 b - 65.3 c</td>
<td>2.17</td>
</tr>
<tr>
<td>Déchet de brasserie</td>
<td>3.58 a - 27.3 b - 69.2 c</td>
<td>2.30</td>
</tr>
<tr>
<td>Levure de boulangerie</td>
<td>4.23 a - 33.8 b - 61.9 c</td>
<td></td>
</tr>
<tr>
<td>Levure de bière séchée</td>
<td>4.19 a - 61.5 c - 34.3 b</td>
<td>0.52</td>
</tr>
<tr>
<td>Levure de bière séchée</td>
<td>7.93 a - 71.4 c - 20.7 a</td>
<td>0.28</td>
</tr>
</tbody>
</table>

**Optimisation des attractifs**

Dans toutes les expériences effectuées, on ne note aucun effet significatif au seuil de 5 % du facteur «sexe» ou du facteur «jour». Le seul facteur pris en compte est donc le facteur «produit».


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La modification du pH du Buminal de pH 6 à pH 3 double son attractivité. Par contre, la modification du pH de la levure de Torula de pH 9 à pH 7 et au delà, ainsi que celui de la levure de boulangerie de 5 à 3 diminuent leur attractivité. L’augmentation du pH de la levure de Torula de pH 9 à pH 10.5, ainsi que celui de la levure de boulangerie de pH 5 à pH 6 augmentent significativement leur attractivité. Une augmentation supplémentaire au delà de ces deux valeurs ne modifie pas (levure de Torula) ou diminue (levure de boulangerie) l’attractivité. Les modification du pH du déchet de brasserie n’influencent pas sur son attractivité. (Figure 1).

L’addition de borax au Buminal ou au Nulure réduit considérablement leur attractivité. Aux trois concentrations de borax testées, l’attractivité du Buminal n’est pas significativement différente de celle du témoin. Le Nulure additionné de borax reste plus attractif que le témoin mais significativement moins attractif que le Nulure seul (Figure 2).

**Figure 1** Influence de la modification du pH sur l’attractivité relative du Buminal, de la levure de boulangerie, du déchet de brasserie et de la levure de Torula.
Moyennes de captures ± l’erreur standard.

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**Développement et optimisation d’attractifs alimentaires pour la mouche du melon *Bactrocera cucurbitae* Coquillett) (Diptera: Tephritidae). Rousse P et al.**


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**Figure 2** Influence de l’ajout de borax sur l’attractivité du Buminal et du Nulure. Moyennes de captures ± l’erreur standard.

**DISCUSSION**

Nous avons montré que la levure contenue dans les déchets de brasserie, ainsi que la levure de boulangerie, sont de bons attractifs pour *B. cucurbitae*. Avec plus du double de captures par rapport au Buminal, le déchet de brasserie présente même une attractivité comparable à celle de la levure de Torula, actuellement le meilleur attractif connu pour les femelles de nombreuses espèces de Tephritidae.

Nos résultats avec les déchets de brasserie correspondent à ceux obtenus par Lloyd avec des concentrations comparables vis-a-vis de *B. tryoni* et *B. neohumeralis* (Lloyd and Drew 1996). Ils diffèrent cependant d’études antérieures menées avec *B. cucurbitae* en plein champ (Gopaul et al. 2000). La méthode de préparation que nous avons utilisée est cependant différente, puisque dans les deux travaux cités, les auteurs utilisent du déchet réduit au maximum par évaporation, puis traité à la papaïne et finalement dilué.


Lors de recherches futures, il serait donc intéressant de s’interroger sur la nature des composés volatils issus des levures et qui sont responsables de la réponse des mouches. S’agit-il de composants biochimiques des cellules, libérés par lyse chimique ou enzymatique, ou plutôt de composés issus du métabolisme des cellules et dont la production pourrait être augmentée à l’aide de conditions et de substrats appropriés? Ou bien, comme le suggèrent certains auteurs, cette attractivité serait en partie liée à des composés volatils non identifiés qui seraient émis par des bactéries associées aux appâts (Prokopy et al. 1992). La réponse à cette question permettrait peut-être d’ouvrir de nouvelles voies en vue de l’optimisation de ces attractifs.


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Développement et optimisation d’attractifs alimentaires pour la mouche du melon *Bactrocera cucurbitae* Coquillet (Diptera: *Tephritidae*). Rousse P et al.


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MODIFICATION AND LABORATORY EVALUATION OF WASTE BREWER’S YEAST, A LOCAL SUBSTITUTE FOR PROTEIN HYDROLYSATE IN MELON FLY BAIT

P Sookar, SI Seewooruthun and FB Khayrattee

Ministry of Agriculture, Food Technology and Natural Resources

ABSTRACT

Waste brewer’s yeast (WBY) was modified to produce 49 different baits with different concentrations of papain enzyme powder, fresh pawpaw juice and fresh pineapple juice as protein digestors and at different proteolysis times. The mean pH, % dry matter and % crude protein of the baits were 6.4, 22 and 9 respectively. The baits were screened with reared melon fly, Bactrocera cucurbitae (Coquillett). All prepared baits were more attractive to the melon fly compared to the water control but less attractive than protein hydrolysate. Relative attractancy compared to protein hydrolysate, ranged from 0.34 to 0.84, 0.35 to 0.43 and 0.25 to 0.68 for WBY modified with the addition of papain enzyme powder, pineapple juice and pawpaw juice, respectively.

Keywords: Bactrocera cucurbitae, melon fly, protein bait, waste brewer’s yeast, laboratory bioassay

INTRODUCTION

Fruit flies of the Family Tephritidae, which include the Natal fly Ceratitis rosa (Karsch), the Medfly C. capitata (Wiedemann), the ber fly Carpomyia vesuviana Costa, the peach fruit fly Bactrocera zonata (Saunders) and the melon fly B. cucurbitae (Coquillett) are some of the most destructive and important pests of fruits and vegetables in Mauritius. The hosts of the melon fly include cucumber Cucumis sativus L., melon Cucumis melo L., watermelon Citrullus lanatus (Thunb.) Mats, squash Cucurbita pepo L., pumpkin Cucurbita maxima Duch, calabash Lagenaria siceraria (Mol.) Stand, ridgegourd Luffa acutangula (L.) Roxb., bittergourd Momordica charantia L., snakegourd Trichosanthes cucumerina L. and chayote Sechium edule (Jacq.) Sw. (Anon, 1998). The melon fly attacks sound and damaged vegetables by laying eggs under the skin. The eggs hatch into larvae that feed in the decaying flesh of the vegetable. Infested vegetables quickly become rotten and inedible or drop to the ground prematurely, thus causing considerable losses in production. If uncontrolled, this pest can destroy the whole harvest.

After the setting up of the National Fruit Fly Control Programme (NFFCP) in 1994, imported protein hydrolysate has been used in bait sprays for control of fruit flies (Soonnoo et al., 1995; Permalloo et al., 1998 and 2000). The effectiveness of the bait sprays relies on the fact that both male and female fruit flies require protein for their growth and development (Christenson and Foote, 1960; Bateman, 1972). This method of control has several advantages over the conventional insecticide cover sprays as they limit the amount of insecticide used, leave lower residues in crops and in the environment, and cause negligible harm to beneficial insects (pollinators and parasites) (Galun et al., 1983). In the bait application technique, Rasamimanana (1997) reported that imported protein hydrolysate is costly in Mauritius, comprising approximately 15% of total costs or 75% of non-labour costs. The ability of Mauritius to produce its own substitute protein bait could make a major contribution to reducing the cost and enhancing the sustainability of fruit fly control activities in the country. In Australia, waste brewers’ yeast (WBY) has been successfully modified into protein bait for control of fruit fly by the Queensland Department of Primary Industries in Brisbane (Lloyd and Drew, 1997). In Mauritius, neutralized WBY was used as a source of protein to replace the imported protein hydrolysate in the bait sprays for the eradication of the oriental fruit fly, Bactrocera dorsalis (Hendel) (Seewooruthun et al., 1998). Unfortunately the neutralized WBY damaged the spare parts of the knapsack sprayers and showed phytotoxicity effects on young leaves of pawpaw and cucurbits (Permalloo, pers. comm., 2001). Nonetheless, good results were obtained as shown by the success of the B. dorsalis eradication campaign (Seewooruthun et al., 2000). The Indian Ocean Commission Regional Fruit Fly Control
Modification and laboratory evaluation of waste brewer’s yeast, a local substitute for protein hydrolysate in melon fly bait.

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Programme carried out preliminary studies on the modification of WBY to produce an autolysate with imported papain enzyme powder. This autolysate was tested in McPhail traps in orchards. It was found to be as effective as the currently imported product when used in the traps (Gopaul et al., 2000a and 2000b).

The objective of the present study was to prepare several baits using different levels of protein digestors, namely papain enzyme powder, fresh pawpaw juice and fresh pineapple juice at different proteolysis times. Ultimately, the prepared baits were bioassayed in the laboratory with reared melon fly.

METHODOLOGY

Modification of WBY

WBY slurry was obtained at the local brewery, Mauritius Breweries Ltd at Phoenix and boiled for two hours with constant stirring on a magnetic stirrer hot plate, model HB 500 to kill the yeast cells so as to stop any further fermentation. The boiled WBY was used to prepare 49 bait formulations using different concentrations of protein digestors (Tables 1 - 3) and proteolysis times (6, 12, 18 and 24 hours) at a temperature of 70°C in a shaking water bath, model OLS 200. A total of 49 baits were prepared, including a control (boiled WBY).

Analysis of prepared baits

The Agricultural Chemistry Division of the Agricultural Services, Réduit carried out the analysis of the prepared baits to determine pH, dry matter and crude protein content.

Laboratory bioassay

A two choice bioassay (attractancy test) was carried out in the laboratory during the month of August and September 2000. The attractancy of each bait was compared with water in a non-competitive environment (i.e., no other bait was present). Protein hydrolysate was used as the standard bait. The experiment was carried out using female melon flies that were 10 to 16 days old. They were protein-deprived flies fed on sugar and water only since their eclosion. Twenty flies were released into a small gauze cage (30 x 30 x 30 cm). Four cages of flies and one bait was tested at any one time in the laboratory. During the experimental period, the temperature and relative humidity ranged between 26°C to 30°C, 70 to 75 %, respectively, and constant artificial lighting was provided.

Ten minutes prior to the start of each test, sugar and water were removed from the test cages and two dry sponge squares (4 cm²) were placed on the gauze top of each cage in diagonally opposite corners. This allowed the flies to investigate the dry sponges prior to introduction of the test bait. At the start of each test, 1 ml of water was applied to one sponge square (the control) and 1 ml of diluted bait (1 to 6 dilution) was applied to the other sponge square in each cage (the test). The sponges were inverted on to the top of the cage so that the flies had direct access to both water and the test bait. The number of flies on each sponge was counted at intervals of two minutes for 10 minutes (five times) and the cages were rotated 180° after five minutes. The maximum number of flies feeding on each sponge during the test time was counted.

On any one test day, four runs of tests were conducted between 08.30 and 12.30 hours (i.e. 08.30 to 09.30, 09.30 to 10.30, 10.30 to 11.30 and 11.30 to 12.30 hours). Each run consisted of four replicate cages of the same bait and the series of tests were repeated on four consecutive days using flies from the same cohort, but varying the times at which each bait was tested on each day. Each bait was thus tested 16 times. Flies were tested once and then discarded. A clean gauze cage and new sponges were used for each test in order to avoid any interference during the test from regurgitated fluid, which might have been deposited on the gauze by flies after feeding.

The relative attractancy of each bait to the standard was expressed as the ratio of the mean maximum number of flies attracted to the standard protein hydrolysate bait during the same period of time. Results were analysed by analysis of variance (ANOVA) in Excel and the means were separated by the least significant test (LSD) at P = 0.05.
RESULTS AND DISCUSSION

Analysis of baits

The baits prepared with the addition of the protein digestors namely papain enzyme powder, fresh pawpaw juice and fresh pineapple juice, had a higher pH (6.4 ± 1.2) as compared to the pH of boiled WBY (5.6 ± 1.5). The percentage dry matter of protein hydrolysate (52%) was twice that of the prepared baits. The mean crude protein content of the prepared baits (9%) was seven times lower than that for protein hydrolysate. The different concentrations of the digestor used coupled with the proteolysis time caused minimum change to the bait pH as shown in Tables 1 to 3. There was no relationship between the concentration of protein digestors namely papain enzyme powder, pineapple juice or pawpaw juice and proteolysis time.

Laboratory bioassay

All prepared baits were more attractive to the melon fly compared to the water control but less attractive than protein hydrolysate. Relative attractancy compared to protein hydrolysate ranged from 0.34 to 0.84, 0.25 to 0.68 and 0.35 to 0.43 for WBY modified by the addition of papain enzyme powder (Table 1), fresh pawpaw juice (Table 2) and fresh pineapple juice (Table 3), respectively. A relative attractancy of 0.34 was obtained for boiled WBY, which indicated that it was attractive to the melon flies without further treatment. Boiling presumably caused sufficient cell lysis without additional enzyme proteolysis or acid hydrolysis. Lloyd and Drew (1997) reported that brewer’s yeast is a rich source of the B-complex vitamins, protein (essential amino acids), and minerals. The liberation of the essential nutrients after proteolysis could be responsible for attracting the melon fly in the tests. A bait with higher crude protein content could result in the release of more essential nutrients. The mean crude protein content of the prepared baits, 9% was seven times lower than that for protein hydrolysate. The prepared baits were less attractive to the melon fly than protein hydrolysate possibly because of their lower crude protein content. Lloyd and Drew (1997) obtained a higher relative attractancy of modified WBY by using more concentrated bait. Several scientists have shown that the attractancy of a protein bait to fruit flies is related to the bait pH among other factors. Mazor et al. (1987) reported that increasing the pH of the acidic protein baits Buminol and Nasiman resulted in increased attraction of laboratory reared female C. capitata in olfactometer choice tests. They determined that this increased attraction was related to, but not solely dependent on, the release of ammonia from the baits as well as the release of other volatiles. Heath et al. (1994) found that the addition of 1-10% borax to 10% Nulure solution increased bait pH, which corresponded directly with increase in number of female C. capitata trapped in field trials. The lower relative attractancy, 0.34 obtained by boiled WBY compared to those modified with the protein digestors could be explained by the fact that boiled WBY had a lower pH, 5.6±1.5 as compared to the mean pH, 6.4±1.2 of baits prepared with protein digestors. An increase in proteolysis time and concentration of digestors produced baits with higher relative attractancy for baits modified by the addition of either papain enzyme powder or pawpaw juice (Tables 1 and 2). It could be that the digestors, being enzymes, an increase in proteolysis time could allow them to digest more yeast cells, thus making more protein available. Furthermore an increase in concentration of the digestor caused more proteolysis of yeast cells resulting in an increase in relative attractancy.

The relative attractancy of baits produced by the addition of pineapple juice increased with an increase in the amount of digestor, but it did not increase linearly with longer proteolysis time (Table 3). There were two protein digestors in the fresh pineapple juice, namely bromeline and citric acid. Most probably, the amount of bromeline was not high enough to cause more yeast cell lysis with longer proteolysis time. The main digestor in the pineapple juice could have been citric acid. Diurnal variation in feeding behaviour of the melon fly was observed. All the tested baits showed a significantly higher ($P<0.05$) relative attractancy when tested between 08.30 and 10.30 hours when compared to those tested between 11.30 and 12.30 hours (Figures 1, 2 and 3). Christenson and Foote (1960) studied the behaviour of B. dorsalis in the fields. They reported that the flies devoted more time searching for food in the morning hours immediately after a prolonged period of inactivity during the night. In contrast, during the day, the flies spent less time on feeding. Laboratory observations on B. tryoni, B. cucurbitae and B. dorsalis suggested that feeding is more prevalent in the morning.
Modification and laboratory evaluation of waste brewer’s yeast, a local substitute for protein hydrolysate in melon fly bait. *P Sookar et al.*

(Suzuki and Koyama, 1980 and Arakaki et al., 1984). This behaviour was also observed in this laboratory bioassay with the tested melon fly.

**Table 1** Baits prepared with papain enzyme powder

<table>
<thead>
<tr>
<th>Bait no</th>
<th>Proteolysis time (hours)</th>
<th>Papain enzyme powder (% w/v)</th>
<th>Bait pH</th>
<th>Relative attractancy</th>
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**Table 2** Baits prepared with fresh pineapple juice

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Modification and laboratory evaluation of waste brewer’s yeast, a local substitute for protein hydrolysate in melon fly bait.

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**Table 3** Baits prepared with fresh pawpaw juice

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<tr>
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<th>Fresh pawpaw juice ( % v/v )</th>
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<td>4</td>
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**Figure 1** Relative attractancy of baits modified with papain enzyme powder in relation to time of bioassay
Figure 2  Relative attractancy of baits modified with pineapple juice in relation to time of bioassay

Figure 3  Relative attractancy of baits modified with papaw juice in relation to time of bioassay
Modification and laboratory evaluation of waste brewer’s yeast, a local substitute for protein hydrolysate in melon fly bait. 

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CONCLUSION

Protein hydrolysate was more attractive to the melon fly as compared to the prepared baits. The percentage solids of the WBY could be increased further by boiling before the addition of protein digestors so that more volatiles are eventually liberated to attract the melon fly.

ACKNOWLEDGEMENTS

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Modification and laboratory evaluation of waste brewer’s yeast, a local substitute for protein hydrolysate in melon fly bait. 

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ABSTRACT

The white grub Hoplochelus marginalis was reported for the first time in 1981 in Réunion Island. Strict quarantine measures have been taken to prevent entry of this pest into Mauritius. These include rescheduling of aircraft flights and movement of ships between the two islands during the active flight period of the adult beetles; chemical treatment around the airport and public awareness campaigns. These measures have been successful as the grub has not been detected in light trappings or soil samplings carried out every year. On several occasions, adult beetles have been intercepted on board aircraft or ships.

Keywords: white grub, quarantine, chemical treatments, light traps

INTRODUCTION

Hoplochelus marginalis Fairmaire is indigenous to Madagascar. It had not been recorded elsewhere prior to its discovery in Réunion Island in 1981 (IRAT 1982). It was probably present in that region, two to three years before that. Damage inflicted to sugar cane was considerable and immediate action was taken in Réunion to counter the spread of the pest. It is considered to have entered Réunion Island in 1972 (Vercambre et al. 1991) when French nationals were being evacuated from Madagascar to Réunion and potted plants were brought in by some of them (Vercambre et al. 1988). In 1981, some 4000 ha were already infested including uncultivated land, ravines, etc (Grivault 1988).

Biology and behaviour

Hoplochelus marginalis is a typical melolonthid beetle commonly called chafer beetles and all have similar general habits. The beetles are stout bodied, fly heavily and walk awkwardly but are adept at burrowing in soil where they spend most of their lives. Adults can be captured from end October to early February. They emerge from the soil at night to feed and mate. They fly between 6.30 p.m and 8.15 p.m (IRAT, 1983; Vercambre et al. 1988). Their flight period lasts 30-45 minutes. Shortly before sunrise, they return to the soil. The foliage of various plants is eaten but the beetles are not voracious feeders, appearing to be sustained largely by nutritional reserves acquired during larval life. The beetles are thus of no significance to plants as pests. Massive flights are triggered by the summer rains (Grivault 1988). In flight, the adults are attracted towards artificial lights and can be readily caught in light traps. Freshly emerged adults have no ripe eggs in their ovaries. It is only after three to four weeks that they start laying eggs. Males have a life span of three to six weeks while the female life span is six to eight weeks. One female can lay up to 50 eggs, mostly in the upper seven to eight cm of soil. Eggs hatch after two weeks (Basso-Bert 1988).

The larvae of H. marginalis and all scarab beetles are known as white grubs. They are of characteristic form, having a whitish, fleshy body - curved like the letter 'C' when at rest. The only hard part of the body is the head, which is brownish and bears powerful biting mandibles. Three larval stages occur during development and nourishment is derived from soil humus and living roots. The fully-grown larva pupates in a cell it makes in the soil.
Larval life lasts eight to ten months. Of the three larval stages, the last is by far the longest and most voracious. The larvae are, like the adults, not host specific. They are capable of feeding on all kinds of roots and tubers and can thus damage various valued plants - vegetables, ornamentals, lawns etc. Sugar cane fields have proved to be the preferred environment of several species, i.e. the environment in which they achieve greatest density.

In sugar cane when there is extreme root damage, the cane tufts can be easily pulled out of the ground. The damage is a function of grub size and grub population density but in any particular combination of these, the symptoms and ultimate cane loss are influenced by the whole gamut of factors that influence cane growth. According to data from Réunion Island, the threshold there for *H. marginalis* is four to six grubs per stool, or where distinct stools are not evident, one grub per millable cane.

A prepupal stage occurs towards the end of the last larval stage. At this stage feeding stops and a cell is made in the soil for pupation. Pupae are found as from mid-September. The pupal stage lasts three to four weeks.

**Measures taken in Réunion Island to cope with this pest (Grivault 1988)**

- Implementation of procedures to prevent secondary foci of infestation resulting from accidental dispersion of immature stages and adults (propaganda, legislation, control of movement of crop produce and other materials).
- Intensive research on the biology of the insect to rationalise advisory work and control measures.
- Investigation of the influence of agronomic practices on the insect and on cane damage (tillage, time of planting, cane varieties, etc.).
- Experimentation on insecticidal control of the insect in soil.
- Research on biological control by entomophagous insects and entomopathogens.

The results of these endeavours were very successful in the sense that the progression of the infestation was delayed. It was only in 1995 (nearly 15 years after initial identification of the insect) that the pest had spread to the whole of the island. The bionomics of the pest was elucidated. The best insecticide available for the control of the pest was the controlled-release formulation of chlorpyrifos (Suxon Blue®) applied in furrows at planting (Basso-Bert 1988). This product gives long-lasting (up to three years) control. Biological control through the introduction of entomophagous insects was quickly abandoned after several unsuccessful attempts (Vercambre et al. 1991). The best biocontrol measure was with the entomopathogenic fungus *Beauveria brongniartii*. A strain of this fungus was collected in Madagascar by the entomologist of IRAT-Réunion and proved very effective. Present recommendations for the control of the white grub in Réunion Island is the application of Suxon Blue® and Betel®, a formulation of *Beauveria brongniartii* at planting.

**Prognosis for Mauritius**

It is a fact that an insect population once introduced in a new environment will often explode after its establishment. In their country of origin, these insects are normally innocuous (e.g. *Phyllophaga smithi* Arrow from Barbados to Mauritius; *Hoplochelus marginalis* from Madagascar to Réunion). The course of events *H. marginalis* could take, if it is introduced into Mauritius, cannot be predicted with certainty. However, the chances are that the insect would cause considerable damage and behave much as it has done in Réunion. Should the insect enter Mauritius, it is highly probable that its presence would not be detected until it had multiplied to some extent and established a colony. There would then be slow extension of the initial focus much as the pattern it took in Réunion or the extension of *P. smithi* in Mauritius. The latter took some thirty years to extend over the whole island. It was first detected in Mauritius at Réduit in 1907 and it is believed to have been imported from Barbados when rooted sugar cane was imported. Its exact date of introduction is not known. It spread over the island in the mid-1930’s (Williams and Ganeshan, 2000).

The nature of impact that *H. marginalis* would have on the Mauritian sugar industry:

1. Reduced cane yields in affected areas.
2. Replanting of severely damaged cane fields.
3. Possible need to shorten the crop cycle.
Preventive measures against the entry of the Sugar cane white grub *Hoplochelus marginalis* (coleoptera: melolonthidae) into Mauritis. M Chinappen et al.

4. Increased cost of production due to insecticide treatments.
5. Possible adverse effects of insecticide treatments on the cane field ecosystem where insecticides have never been utilised for the control of existing pests.

**Measures taken to prevent entry into Mauritius**

Due to the proximity of Réunion Island and the potential threat of this pest to Mauritian agriculture, regular meetings and visits have been carried out since 1981 to follow the spread of the infestation in Réunion Island. On 19 October 1990, a Protocol was signed by the Mauritian and French Authorities defining agreed measures that both countries would enforce to minimize the risks of introducing white grubs from one country to the other. The measures include:

1. **Rescheduling of plane flights:** During the active flight period of the beetles, between 1 November and 31 January, no aircraft to depart Réunion Island towards Mauritius after 6.30 p.m until 8.30 p.m.
2. **Treatment of luggage holds:** Luggage holds of all planes taking off towards Mauritius to be insecticide treated. Moreover, the luggage holds and cabin of aircraft staying in Réunion Island overnight are to be treated, prior to take off the next day, with an insecticide approved for use in aviation.
3. **Air freight:** Freight stored outside for eventual shipment should be kept in dark areas.
4. **Restriction on movement of ships:** When ships due to depart towards Mauritius are at port, all light sources in the vicinity of the ships to be switched off and a total black-out of all entry points (cabin, holds, etc.) be observed during the flight period. The ships to be inspected in Réunion Island by the *Service de la Protection des Végétaux* (SPV) and cleared for departure.

Communication is an important aspect of the Protocol. Thus every year light traps are operated in Réunion Island, at the ports and airports, by the SPV and results are communicated to Mauritius everyday (by e-mail / fax).

In addition to the measures listed in the protocol, preventive measures are also taken in Mauritius. These include:

1. **Preventive insecticide treatment:** Within a 500 m radius around SSR International Airport in February-March in case any beetles might have escaped and laid eggs. This comprises wastelands within airport premises, lawns, car parks and sugar cane fields. The insecticide ethoprophos (Mocap®) is applied over an area of approximately 20 ha by the Ministry of Agriculture and Mon Trésor Sugar Estate.
2. **Public awareness campaigns:** Another route of entry of the pest into Mauritius is through luggage. Posters have been placed in the airport and leaflets are distributed to all passengers to inform them of the threat this insect poses to Mauritian agriculture.
3. **Treatment and release of beetles:** When the insect population around the Roland Garros Airport in Réunion Island was at its peak (between 1994 and 1997), beetles were treated with the entomopathogenic fungus *Beauveria brongniartii* and released to contaminate the region to reduce the larval intensity. This exercise was eventually extended to other regions in Réunion Island and is now carried out on a routine basis.
4. **Soil samplings:** Between June and August, surveys are carried out, in regions such as the airport, the port, Rivière Noire and Grand Baie which are considered 'hot spots', to detect larvae. The Ministry of Agriculture as well as the MSIRI are involved in this exercise.
5. **Light trapping:** Light traps are placed during the flight period of the beetle at the airport, port, Grand Baie and Rivière Noire by the Ministry of Agriculture. The MSIRI carries light trappings in sugar cane fields in the above regions and also on several sugar estates.
6. **Collaboration at national level:** Each year meetings are held with the economic operators (Airlines, Shipping Agents, Police, Civil Aviation, Airports of Mauritius, Cargo Handling Corporation, Customs, and representatives of various Ministries) to keep them informed about the situation and to enlist their collaboration in proper implementation of the Protocol.

**Interception of beetles on board aircraft and ships**

All planes and ships coming from Réunion Island are systematically inspected by Quarantine Officers. On several occasions, live or dead beetles have been intercepted. Upon detection of live beetles on board ships, the Captain is requested to move the vessel to high seas where the ship is thoroughly washed before re-entry in the port.

**CONCLUSION**

*Hoplochelus marginalis* can be cited as an example of successful quarantine measures since so far the insect, although having been present in Réunion Island for more than 20 years, has not been found in Mauritius. This has been achieved through the collaboration of all stakeholders. It has been observed that during the past years the insect population in Réunion Island is decreasing probably due to the systematic application of the insecticide chlorpyrifos and the entomopathogenic fungus *Beauveria brongniartii* in all newly planted cane fields. However, vigilance on the Mauritian side should be maintained because the risk of entry into Mauritius is still high.

**ACKNOWLEDGEMENTS**

We are grateful to the Chief Agricultural Officer, the Principal Agricultural Officer, the staff of the Quarantine Services and of the Entomology Division of the Ministry of Agriculture, the Director and the Deputy Director of the MSIRI, the SPV in Réunion Island for all facilities and support granted for the implementation of the white grub protocol.

**REFERENCES**


Preventive measures against the entry of the Sugar cane white grub *Hoplochelus marginalis* (coleoptera: melolonthidae) into Mauritius. *M Chinappen* et al.

SOME EFFECTS OF THE SOFT SCALE *PULVINARIA ICERYI* (SIGN.) (HOMOPTERA: COCCIDAE) ON SUGAR CANE

*AG Soma* and *S Ganeshan*

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ABSTRACT

A major outbreak of the sugar cane soft scale *Pulvinaria iceryi*, an occasional pest of sugar cane in Mauritius, occurred in 1976/1977 when approximately 4000 ha were affected. In subsequent years, although present in sugar cane fields, it never reached damaging proportions. However, localised infestations have been recurring since 1997 and in 2001 and 2002 about 150 ha were severely infested. The effect of *P. iceryi* on mature sugar cane was assessed in six fields. Cane samples with slight, moderate and severe damage were taken from infested fields and compared with uninfested canes for brix, pol % cane, juice purity and fibre % cane. Cane height and number of internodes were also recorded. There was no significant difference in cane height and number of internodes. Moderate or severe infestations by *P. iceryi* significantly reduced brix, pol. % cane and juice purity. Fibre % cane was not affected. Reduction in IRSC ranged between 18 and 69%. These results illustrate the damaging nature of this pest, which needs to be constantly monitored in sugar cane fields.

Keywords: sugar yield, juice purity, IRSC, damaged canes

INTRODUCTION

The first observed attacks of the soft scale, *Pulvinaria iceryi* Signoret (Homoptera: Coccidae) in Mauritius were in 1863 and it devastated sugar cane plantations (Williams, 1978; 1980). The pest is commonly known as ‘pou à poche blanche’ because of its white ovisac. Apart from sugar cane, it has also been observed on many Graminae and some other plant families (Mamet and Williams, 1993; Williams, 1978). It is generally found as occasional individuals, though limited outbreaks occur sporadically; the insect when abundant can have drastic effects on sugar cane (Rao and Sankaran, 1969; Williams, 1978). *Pulvinaria iceryi* has the propensity for rapid multiplication. According to Williams (1978), fecundity can exceed one thousand eggs per female.

The pest is usually found on the underside of leaves where it feeds on the phloem (Carnegie, 1994). On feeding, the insect removes from the conducting elements the plant nutrients, while the injected saliva into the plant tissues during feeding has a toxic action (Williams, 1978). Infested leaves show characteristic yellowish, bordeaux-red or violet colourations before drying up (Rao and Sankaran, 1969). *Pulvinaria iceryi* excretes copious amounts of honeydew which fall on the foliage where a sooty mould may develop. Heavy infestations result in reduction of growth, and even in the death of shoots and stools (Carnegie, 1994). The nature of losses that result from crop infestation are loss of cane yield, loss of millable sugar in cane, costs of recruiting and replanting killed canes and loss of cane yield in subsequent crop from poor ratooning (Williams, 1978).

A small outbreak occurred in 1955, confined to only two localities in the North of the island where about 13 ha were affected (Williams, 1978). In 1959, 2 ha were infested in the South where about 1 ha was completely destroyed (MSIRI, 1960; Williams, 1978). The most important and serious outbreak occurred in 1976-1977 which resulted in great economic loss. The outbreak was widespread and many fields were seriously infested. It was estimated that about 4000 ha were affected causing an estimated loss of about 200000 t of cane or 25000 t of sugar (MSIRI, 1977; Williams, 1978). The cause of that sudden recrudescence of *P. iceryi* was uncertain but it was believed that it was linked with weather conditions that upset natural balances. In subsequent years, infestations were limited to small patches of cane. These foci eventually disappeared, due to the intense activity of hymenopterous parasitoids and there was no significant economic loss (MSIRI, 1979; 1980; 1981).
Some effects of the soft scale *Pulvinaria iceryi* (Sign.) (Homoptera: Coccidae) on sugar cane. AG Soma and S Ganeshan

The population of *P. iceryi* is normally kept under control by the action of several natural enemies. The most common ones are the aphelid parasitoids *Coccophagus cowperi* Gir. and *Aneristus ceroplastae* How. and the coccinellid predators, *Cryptolaemus montrouzieri* Muls., *Exochomus laeviusculus* Wse, and *Hyperaspis hottentota* Muls. (MSIRI, 2002). A thorough trashing and removal of all yellowing leaves followed by a careful subsequent monitoring of the field can be effective in case of a slight infestation, that is, when a few larvae and adults are present. A severely infested field should, however, be cut back (stubble shaved) leaving the cane shoots to dry *in situ* between the rows to allow natural enemies which are on them to disperse (Anon, 2001). It is also advisable not to burn infested fields, not to replant fields adjacent to infested ones and not to allow field workers to move from infested to healthy fields.

Small foci of infestation of *P. iceryi* have been regularly observed in recent years in the southern part of the island but in 1999 an upsurge of infestation occurred in several regions (MSIRI, 2000). A year later, about 160 ha were severely infested and the outbreak was considered to be the most extensive recorded since 1976 (MSIRI, 2001). Immediate action was taken where all severely infested fields, about an area of 28 ha, representing about 2400 t of cane, were cut back and stubble shaved to prevent spread of infestation to neighbouring regions. It was also noted that heavy predation and parasitism of the scale developed in the severely infested fields, which helped to check effectively the increase of the pest population. In 2001, *P. iceryi* continued to affect sugar cane plantations and infestation was observed in about 150 ha of which 45 ha had severe damage and were stubble shaved (MSIRI, 2002).

The aim of this study was to quantify the losses caused by *P. iceryi* in sugar cane well before death of canes.

**MATERIALS AND METHODS**

Cane samples were taken in 2002 from fields infested with *P. iceryi*. Fields selected were those of mature canes near harvest, with varying degrees of infestation. Six fields were sampled (*Table 1*). Cane samples from each field were categorized as follows:

- Uninfested canes
- Slight infestation: beginning of chlorosis; there are a few adults or larvae on some leaves.
- Moderate infestation: when 50% of leaves have attained chlorosis and some individuals of the pest are present.
- Severe infestation: complete chlorosis and/or all leaves with an innumerable number of all stages of the insect.

*Table 1* Cropping attributes of fields surveyed

<table>
<thead>
<tr>
<th>Estate</th>
<th>Section</th>
<th>Variety</th>
<th>Category</th>
<th>Date of plantation / Date of last harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon Tresor</td>
<td>Sauveterre</td>
<td>M 695 / 69</td>
<td>Plant Cane</td>
<td>21 Aug 01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M 1400 / 86</td>
<td>Plant Cane</td>
<td>17 Oct 01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R 570</td>
<td>5th ratoon</td>
<td>28 Jul 01</td>
</tr>
<tr>
<td>Beau Champ</td>
<td>Ferney</td>
<td>M 695 / 69</td>
<td>4th ratoon</td>
<td>17 Jul 01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M 1658 / 78</td>
<td>6th ratoon</td>
<td>8 Sep 01</td>
</tr>
<tr>
<td></td>
<td>Olivia</td>
<td>R 570</td>
<td>5th ratoon</td>
<td>29 Oct 01</td>
</tr>
</tbody>
</table>

From each field ten samples, each of six stalks, of each category, were taken.

For each sample, the length of each cane and number of internodes were noted. The samples were weighed and analysed for brix, pol % cane, juice and fibre % cane, and IRSC (Industrial recoverable sucrose % cane) was calculated.
RESULTS AND DISCUSSION

Results are given in Tables 2 - 7 and in Figure 1.

The effect of the soft scale on the growth of the cane plant was not evident in most of the fields surveyed. There was no appreciable reduction in the number of internodes of infested canes. It should be emphasized that infestation in the fields surveyed occurred at the end of the normal crop elongation phase, which explains why impaired growth was not evident.

Table 2 Effect of infestation by *Pulvinaria iceryi* on cane length (cm)

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570 Sauveterre</th>
<th>Olivia</th>
<th>M 695 / 69 Sauveterre</th>
<th>Ferney</th>
<th>M 1658 / 78 Ferney</th>
<th>M 1400 / 86 Sauveterre</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>259.3</td>
<td>184.9</td>
<td>261.9</td>
<td>287.5</td>
<td>204.4</td>
<td>218.4</td>
</tr>
<tr>
<td>B</td>
<td>233.6*</td>
<td>178.9</td>
<td>278.8</td>
<td>230.8*</td>
<td>170.4*</td>
<td>196.3*</td>
</tr>
<tr>
<td>C</td>
<td>220.3*</td>
<td>186.4</td>
<td>323.5</td>
<td>256.1*</td>
<td>177.6*</td>
<td>220.3</td>
</tr>
<tr>
<td>D</td>
<td>204.7*</td>
<td>180.5</td>
<td>314.9</td>
<td>283.1</td>
<td>159.5*</td>
<td>190.93*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>25.1</td>
<td>22.5</td>
<td>27.3</td>
<td>21.0</td>
<td>18.5</td>
<td>15.9</td>
</tr>
</tbody>
</table>

* Significantly lower than A at P = 0.01

In most fields sampled, pol % cane, juice purity and brix were greatly affected at moderate and severe infestations. Slight infestation had, however, little or no effect on yield parameters. No appreciable change in fibre % cane was observed. The effect of the pest was found to be more pronounced at Olivia (var. R570) where the highest reduction in yield parameters was obtained. The results obtained at Sauveterre (var. M695/69) are worth noting. Although the uninfested canes were of lower maturity, they had significantly higher pol %, juice purity and brix than infested canes.

Table 3 Effect of infestation by *Pulvinaria iceryi* on internodes / cane

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570 Sauveterre</th>
<th>Olivia</th>
<th>M 695 / 69 Sauveterre</th>
<th>Ferney</th>
<th>M 1658 / 78 Ferney</th>
<th>M 1400 / 86 Sauveterre</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20.5</td>
<td>16.1</td>
<td>19.6</td>
<td>21.2</td>
<td>19.3</td>
<td>17.2</td>
</tr>
<tr>
<td>B</td>
<td>21.4</td>
<td>15.7</td>
<td>19.8</td>
<td>19.3</td>
<td>16.7</td>
<td>18.2</td>
</tr>
<tr>
<td>C</td>
<td>21.2</td>
<td>15.6</td>
<td>21.1</td>
<td>21.2</td>
<td>17.6</td>
<td>19.4</td>
</tr>
<tr>
<td>D</td>
<td>18.9</td>
<td>15.3</td>
<td>20.6</td>
<td>22.0</td>
<td>17.0</td>
<td>15.5*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>2.2</td>
<td>1.7</td>
<td>2.2</td>
<td>1.4</td>
<td>4.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>

* Significantly lower than A at P = 0.01

Loss in IRSC ranged from 18% to 69% in severely infested canes (Figure 1). It is evident that the effect of *P. iceryi* depends on the intensity of infestation, that is, with increase in infestation there is a gradual decrease in sucrose content. These results concur with the findings of Williams (1978).

Cane varieties can account for the patterns of infestation in particular areas. In the 1976-77 outbreak, varieties like S 17 were found to be more infested than others and appeared to influence the dissemination of *P. iceryi* (MSIRI, 1978). Most of reports of infestation in the 1990's mention that variety M 695 / 69 was the most susceptible variety (MSIRI, 1993;1999).
Some effects of the soft scale *Pulvinaria iceryi* (Sign.) (Homoptera: Coccidae) on sugar cane. **AG Soma** and **S Ganeshan**

**Table 4** Effect of infestation by *Pulvinaria iceryi* on Brix

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570</th>
<th>M 695 / 69</th>
<th>M 1658 / 78</th>
<th>M 1400 / 86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sauveterre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olivia</td>
<td>3.7</td>
<td>3.3</td>
<td>3.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Ferney</td>
<td>3.2</td>
<td>3.6</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>C</td>
<td>2.9*</td>
<td>3.0*</td>
<td>2.8*</td>
<td>3.2*</td>
</tr>
<tr>
<td>D</td>
<td>2.7*</td>
<td>2.2*</td>
<td>2.8*</td>
<td>3.1*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* Significantly lower than A at $P = 0.01$

**Table 5** Effect of infestation by *Pulvinaria iceryi* on Pol % cane

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570</th>
<th>M 695 / 69</th>
<th>M 1658 / 78</th>
<th>M 1400 / 86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sauveterre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olivia</td>
<td>13.2</td>
<td>11.4</td>
<td>12.1</td>
<td>13.5</td>
</tr>
<tr>
<td>Ferney</td>
<td>11.6</td>
<td>11.9</td>
<td>11.0</td>
<td>12.3</td>
</tr>
<tr>
<td>C</td>
<td>9.6*</td>
<td>9.1*</td>
<td>8.8*</td>
<td>10.2*</td>
</tr>
<tr>
<td>D</td>
<td>8.7*</td>
<td>4.8*</td>
<td>8.7*</td>
<td>9.5*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>1.7</td>
<td>1.1</td>
<td>1.7</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* Significantly lower than A at $P = 0.01$

Subsequently, severe infestation has been observed also in varieties R 570, M 1658 / 78 and M 1400 / 86 (MSIRI, 2001; 2002). The results presented in this paper indicate that loss incurred is irrespective of cane variety. The results obtained at Sauveterre where the three fields (vars. R 570, M 1400 / 86, and M 695 / 69) were adjacent illustrate well this fact.

The findings of this study demonstrate the need to constantly monitor the incidence of the soft scale in sugar cane.

**Table 6** Effect of infestation by *Pulvinaria iceryi* on juice purity

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570</th>
<th>M 695 / 69</th>
<th>M 1658 / 78</th>
<th>M 1400 / 86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sauveterre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olivia</td>
<td>92.2</td>
<td>87.4</td>
<td>89.3</td>
<td>81.2</td>
</tr>
<tr>
<td>Ferney</td>
<td>90.5</td>
<td>89.5</td>
<td>89.7</td>
<td>81.7*</td>
</tr>
<tr>
<td>C</td>
<td>86.0*</td>
<td>78.7*</td>
<td>82.2*</td>
<td>73.4</td>
</tr>
<tr>
<td>D</td>
<td>82.7*</td>
<td>57.7*</td>
<td>82.3*</td>
<td>79.9*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>4.0</td>
<td>6.6</td>
<td>4.3</td>
<td>6.6</td>
</tr>
</tbody>
</table>

* Significantly lower than A at $P = 0.01$
Figure 1 Percentage loss in IRSC for different infestation categories

Table 7 Effect of infestation by *Pulvinaria iceryi* on fibre % cane

<table>
<thead>
<tr>
<th>Infestation category</th>
<th>R 570 Sauveterre</th>
<th>R 570 Olivia</th>
<th>M 695 / 69 Sauveterre</th>
<th>M 695 / 69 Ferney</th>
<th>M 1658 / 78 Ferney</th>
<th>M 1400 / 86 Sauveterre</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>11.96</td>
<td>11.32</td>
<td>12.32</td>
<td>12.18</td>
<td>11.02</td>
<td>10.04</td>
</tr>
<tr>
<td>B</td>
<td>11.40</td>
<td>11.96</td>
<td>12.52</td>
<td>13.34</td>
<td>11.32</td>
<td>10.44</td>
</tr>
<tr>
<td>C</td>
<td>11.54</td>
<td>10.60</td>
<td>11.26</td>
<td>13.22</td>
<td>10.34</td>
<td>9.66</td>
</tr>
<tr>
<td>D</td>
<td>11.30</td>
<td>9.28*</td>
<td>11.78</td>
<td>12.66</td>
<td>10.70</td>
<td>8.32*</td>
</tr>
<tr>
<td>LSD (0.01)±</td>
<td>1.63</td>
<td>0.87</td>
<td>2.17</td>
<td>1.81</td>
<td>0.87</td>
<td>1.48</td>
</tr>
</tbody>
</table>

* Significantly lower than A at $P = 0.01$

Appropriate measures must be taken at first signs of infestation to avoid build up in the pest population which might cause death of canes in extreme cases or sugar loss when infestation is moderate to severe.

REFERENCES

Some effects of the soft scale *Pulvinaria iceryi* (Sign.) (Homoptera: Coccidae) on sugar cane. *AG Soma* and *S Ganeshan*  


VARIATION AND INHERITANCE OF QUANTITATIVE TRAITS IN COMMERCIAL X S. SPONTANEUM L CROSSES

MGH Badaloo and K Ramdoyal
Mauritius Sugar Industry Research Institute

ABSTRACT

Data on agronomic and quality characters were used to derive genetic variance and inheritance of characters, expected selection gains and assess the association between traits in 14 F1 seedling populations obtained from crosses between male sterile commercial varieties and clones of the wild Saccharum spontaneum species. Frequency distributions for agro-morphological and quality characters tended towards normality. There were highly significant genetic differences between full-sib families and heritability estimates varied from low to moderately low for dry matter % cane, fibre % cane and stalk number to moderately high for stalk diameter and high for pol % cane. Phenotypic correlation coefficients established among the agro-morphological and quality characters on both a family and within family basis indicated associations that were close to the parental source and points to the difficulty in increasing sucrose and fibre content concurrently. However, within family correlations indicated that there was the possibility of introgressing desirable characters from the wild S. spontaneum genome into commercial varieties. The expected response to selection indicates good scope to widen the genetic base of sugar cane varieties. Bivariate cross prediction was shown to be robust in the identification of the best crosses for the pair-wise combination of pol and fibre on both a fresh and dry matter basis, stalk number and dry matter % cane, but not for stalk number and diameter and stalk diameter and fibre.

Keywords: germplasm utilisation, interspecific hybridisation, heritability, genetic base, cross prediction, Saccharum spp.

INTRODUCTION

Modern sugar cane cultivars are highly heterozygous interspecific hybrids (2n = 100-130) that originated mainly from the nobilisation of the wild species (Roach and Daniels 1987), by successive crossing and backcrossing to S. officinarum (2n = 80). Within the natural variation of the "Saccharum complex", the following genera: Saccharum, Erianthus Sect. Ripidium, and Miscanthus, have been exploited in sugar cane breeding. S. spontaneum is highly polymorphic, vigorous, with fibrous, thin stalk diameter of low sucrose content, possesses genes for adaptation to biotic and abiotic stresses and has excellent ratooning ability (Panje 1971; Roach 1984; Jackson 1994). S. officinarum is characterised by thick canes of high sucrose content, low fibre, low vigour and is generally susceptible to most of the prevailing diseases (Sreenivasan et al. 1987). S. robustum (2n = 60-80) have tall stalks that grow up to 10 m in height with little juice (Stevenson 1965).

The narrow genetic base of modern sugar cane cultivars has been recognised (Arceneaux 1965, Roach 1989). In Mauritius, the genetic base broadening programme is hindered by asynchronous flowering. S. spontaneum flowers in April whilst flowering of S. officinarum is late (July), shy and erratic. In addition, fertility of such crosses is usually variable (Ramdoyal and Badaloo 2002). Delaying flowering time of S. spontaneum clones by means of night break treatment at the early inflorescence branch primordia stage is often resorted to enable crossing with S. officinarum (Julien 1971; Badaloo et al. 1995). Breeding for increased sugar yield per unit area has resulted in selection against fibre which averages 13% for commercial varieties bred in Mauritius. Bagasse, the fibrous residue, following mill extraction, is converted into electricity and is currently used to power mills during the crop season. Excess energy is sold to the national grid. Interest for increased bagasse has grown up considerably in view of the setting up of cogeneration units within the sugar factory in line with the new strategic plan of the sugar industry (Anon. 2001). The use of bagasse in co-generation has been reviewed (Baguant
1984; Deepchand 2000). In this context, attempts to increase the fibre content of commercial varieties, while maintaining acceptable sucrose levels, for increased bagasse output remain a challenge to breeders.

This paper reports on the extent of genetic variation of some agronomic and quality characters in commercial hybrids × *S. spontaneum* crosses and the association among them, in order to gauge the benefits and difficulties that can be experienced by the direct introgression of wild genome in the commercial background for increased fibre with acceptable sucrose content and other commercial attributes. In addition, pair-wise combination of variates were tested in order to evaluate the potential of crosses to transgress set targets simultaneously for the production of improved parent varieties and/or commercial ones.

**MATERIALS AND METHODS**

Fourteen biparental families, derived from crosses between seven male sterile commercial parents and four clones of *S. spontaneum*, were evaluated in this study. Each family was represented by 48 unselected progenies which were planted in a humid environment at Réduit Experiment Station, altitude 305 m, annual rainfall 1500 mm, mean minimum and maximum temperatures of 14°C and 28°C, with a low humic latosolic soil (Parish and Feillafé 1965).

A randomised complete block design, with three replicates, was used with 16 seedlings per family assigned to each replicate. The progenies were planted in rows spaced at 1.5 m and 0.75 m within rows. Each plant was scored 15 months after field transplanting for: number of cane stalks, stalk diameter (mm) measured on five stalks taken at random. Quality traits were determined from the analysis of cane samples by the method of Saint Antoine and de Froberville (1964) for Brix % cane (total dissolved solids in juice), pol % cane (the apparent sucrose of the juice as determined by polarisation), fibre % cane, dry matter % cane and juice purity was obtained from the ratio of Brix % cane and pol % cane. The first three quality characters were expressed on a dry matter basis. Pol:fibre index was derived from pol % dry matter and fibre % dry matter.

**Statistical analyses and estimation of genetic parameters**

Estimates of the variance components were based on the expected mean squares of the analysis of biparental families (Kearse and Pooni 1996). From expectation of mean squares: $\sigma^2_W = \frac{1}{2}V_A + V_E$ and $\sigma^2_B = \frac{1}{2}V_A$, assuming negligible dominance effects; where $\sigma^2_W =$ expected average variance within full-sib families and $\sigma^2_B =$ expected variance of true family mean, $V_A =$ additive genetic variance and $V_E =$ environmental variance. Narrow sense heritability was calculated as $h^2_n = \frac{V_A}{V_A + V_E}$. The number of progeny per family, $r$ was corrected for unequal number of seedlings as a result of differential mortality (Sokal and Rohlf 1981).

Basic statistics and analyses of variances were derived using Genstat 5 (Digby et al. 1987). The variance and the standard error of variance components were estimated where each variance component is a linear function of mean squares and the mean squares are independent (Anderson and Bancroft 1952). Genetic advance was calculated as $G_i = i h^2_n \sigma_p$, where, $G_i =$ genetic advance, $i =$ intensity of selection (at 5% level), $h^2_n$ and $\sigma_p$ are narrow sense heritability estimate and phenotypic standard deviation respectively (Allard 1960). $G_i$ was expressed as a percentage of the mean to allow comparison among traits. Phenotypic correlations between characters were calculated on both a family mean basis and within each family. Within family frequency distributions of the quality characters were plotted for all the 14 families.

Two cross prediction methods were studied:

1. the sum of ranks (RANK) and
2. the observed frequencies of genotypes that transgress the set targets (FREQ).

The RANK was calculated by ranking the 14 crosses, for each of two selected variates and summing them up to give a total for each bivariate combination (RANK = rank for trait 1 + rank for trait 2) (Brown and Caligari 1988). The observed frequencies (FREQ) were derived by counting the total number of genotypes that exceeded the set target for each of the two variates simultaneously. In general, the set target for each trait was taken as the mean of all crosses. Correlation coefficients were
Variation and inheritance of quantitative traits in commercial x S. spontaneum L crosses. MGH Badaloo and K Ramdoyal


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calculated between the RANK and FREQ statistics for all pair-wise combination of characters. Simultaneous evaluation was performed for example fibre and pol % cane, on both a fresh and dry weight basis, stalk number and diameter as well as stalk diameter and fibre.

RESULTS AND DISCUSSION

For most crosses, the frequency distribution for the quality characters tended towards normality, as is typical of quantitative characters. Tai et al. (1992) observed that the distribution of Brix, sucrose content, juice purity and fibre content in commercial hybrids x S. spontaneum crosses were continuous. Mean and standard deviation, based on a fresh weight and dry weight basis, are presented in Tables 1 and 2 respectively. In general, mean stalk number was very high (18.1 to 35.6) compared to commercial-type crosses (8 to 14) (Badaloo 1997), with a correspondingly smaller stalk diameter (13.2 to 19.6 mm) (Table 1).

**Table 1** Mean and standard deviation for stalk number, stalk diameter and quality characters on a fresh weight basis

<table>
<thead>
<tr>
<th>Cross</th>
<th>Stalk number</th>
<th>Stalk diameter</th>
<th>Brix % Cane</th>
<th>Pol % cane</th>
<th>Fibre % cane</th>
<th>Dry matter % cane</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 684 x IS 76216</td>
<td>23.5 ± 9.0</td>
<td>18.6 ± 3.0</td>
<td>10.5 ± 1.3</td>
<td>7.5 ± 1.4</td>
<td>20.3 ± 2.2</td>
<td>30.9 ± 2.3</td>
<td>0.71 ± 0.07</td>
</tr>
<tr>
<td>D 684 x SSS 2</td>
<td>20.1 ± 8.0</td>
<td>18.3 ± 2.0</td>
<td>12.4 ± 1.6</td>
<td>9.7 ± 1.9</td>
<td>17.8 ± 3.2</td>
<td>30.1 ± 3.3</td>
<td>0.78 ± 0.07</td>
</tr>
<tr>
<td>E 69991 x IS 76216</td>
<td>24.3 ± 8.0</td>
<td>17.2 ± 2.0</td>
<td>10.1 ± 1.0</td>
<td>7.2 ± 2.0</td>
<td>18.4 ± 2.1</td>
<td>28.4 ± 2.4</td>
<td>0.68 ± 0.07</td>
</tr>
<tr>
<td>E 69991 x IK 7610</td>
<td>23.0 ± 9.0</td>
<td>17.7 ± 3.0</td>
<td>9.6 ± 1.4</td>
<td>5.9 ± 1.8</td>
<td>19.8 ± 2.8</td>
<td>29.5 ± 3.1</td>
<td>0.61 ± 0.11</td>
</tr>
<tr>
<td>E 69991 x SSS 2</td>
<td>18.1 ± 8.0</td>
<td>18.8 ± 3.0</td>
<td>11.4 ± 1.1</td>
<td>8.1 ± 1.4</td>
<td>17.8 ± 2.4</td>
<td>29.1 ± 2.8</td>
<td>0.71 ± 0.07</td>
</tr>
<tr>
<td>N 10 x G. Kepandjen</td>
<td>28.6 ± 12.0</td>
<td>13.7 ± 2.0</td>
<td>9.1 ± 1.1</td>
<td>6.1 ± 1.3</td>
<td>20.6 ± 2.4</td>
<td>29.7 ± 2.6</td>
<td>0.66 ± 0.08</td>
</tr>
<tr>
<td>N 13 x IK 7610</td>
<td>19.4 ± 10.0</td>
<td>17.7 ± 3.0</td>
<td>10.0 ± 2.4</td>
<td>6.9 ± 2.8</td>
<td>18.0 ± 3.7</td>
<td>28.0 ± 3.8</td>
<td>0.67 ± 0.12</td>
</tr>
<tr>
<td>N 13 x IS 76216</td>
<td>22.8 ± 13.0</td>
<td>19.6 ± 4.0</td>
<td>12.0 ± 2.1</td>
<td>8.7 ± 2.5</td>
<td>16.5 ± 4.9</td>
<td>28.5 ± 3.8</td>
<td>0.72 ± 0.09</td>
</tr>
<tr>
<td>N 14 x IK 7610</td>
<td>20.7 ± 10.0</td>
<td>18.8 ± 2.0</td>
<td>10.2 ± 1.2</td>
<td>7.1 ± 1.4</td>
<td>19.4 ± 2.6</td>
<td>29.6 ± 3.0</td>
<td>0.69 ± 0.07</td>
</tr>
<tr>
<td>N 14 x IS 76216</td>
<td>24.2 ± 9.0</td>
<td>17.0 ± 2.0</td>
<td>11.4 ± 1.2</td>
<td>8.1 ± 1.5</td>
<td>18.8 ± 2.7</td>
<td>30.2 ± 2.3</td>
<td>0.71 ± 0.07</td>
</tr>
<tr>
<td>NCo 376 x G. Kepandjen</td>
<td>27.9 ± 12.0</td>
<td>13.2 ± 3.0</td>
<td>8.8 ± 1.0</td>
<td>5.1 ± 1.4</td>
<td>20.8 ± 2.6</td>
<td>29.6 ± 2.9</td>
<td>0.58 ± 0.10</td>
</tr>
<tr>
<td>NCo 376 x IS 76216</td>
<td>35.6 ± 12.0</td>
<td>16.8 ± 2.0</td>
<td>10.2 ± 1.7</td>
<td>6.9 ± 1.5</td>
<td>20.1 ± 3.2</td>
<td>30.4 ± 3.6</td>
<td>0.67 ± 0.06</td>
</tr>
<tr>
<td>SP 716113 x IK 7610</td>
<td>18.8 ± 7.0</td>
<td>18.2 ± 3.0</td>
<td>11.2 ± 1.4</td>
<td>8.1 ± 1.8</td>
<td>19.3 ± 2.5</td>
<td>30.5 ± 2.8</td>
<td>0.72 ± 0.09</td>
</tr>
<tr>
<td>SP 716113 x IS 76216</td>
<td>20.7 ± 12.0</td>
<td>19.0 ± 3.0</td>
<td>12.3 ± 1.5</td>
<td>9.6 ± 1.7</td>
<td>18.2 ± 3.3</td>
<td>30.5 ± 2.6</td>
<td>0.78 ± 0.06</td>
</tr>
</tbody>
</table>

Pol % cane ranged from 5.1 to 9.7 and was generally low as expected from these crosses. Fibre % cane and dry matter % cane were quite high ranging from 16.5 to 20.8 and 28.0 to 30.9 respectively. These observations agree with Roach (1969) and Walker (1972) who found that hybrids of commercial cultivars x S. spontaneum have reduced sucrose content and increased fibre content. Sucrose content compared reasonably well with S. officinarum x S. spontaneum crosses (Ramdoyal and Badaloo 2002). These progenies were generally more vigorous and often more attractive than the basic nobilisation crosses. Pol % dry matter ranged from 17.1 to 32.3 and was in general much lower than in commercial-type crosses (41 to 46), whilst fibre % dry matter was much higher, (57.0 to 70.3), compared to commercial-type crosses (44 to 47) (Badaloo 1997). In addition, the pol:fibre ratio was quite low (0.25 to 0.57) and showed a preferential partitioning of dry matter towards fibre. Juice purity levels ranged from 0.58 to 0.78, which is lower than what is expected from commercial-type crosses.
Variation and inheritance of quantitative traits in commercial x S. spontaneum L crosses. MGH Badaloo and K Ramdoyal

Table 2  Mean and standard deviation for quality characters on a dry matter basis

<table>
<thead>
<tr>
<th>Families</th>
<th>Brix % dry matter</th>
<th>Pol % dry matter</th>
<th>Fibre % dry matter</th>
<th>Pol:Fibre ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 684 x IS 76216</td>
<td>34.2 ± 4.1</td>
<td>24.4 ± 4.5</td>
<td>65.8 ± 4.1</td>
<td>0.38 ± 0.09</td>
</tr>
<tr>
<td>D 684 x SSS 2</td>
<td>41.4 ± 5.7</td>
<td>32.3 ± 6.2</td>
<td>58.6 ± 5.7</td>
<td>0.57 ± 0.17</td>
</tr>
<tr>
<td>E 69991 x IS 76216</td>
<td>35.5 ± 3.3</td>
<td>24.3 ± 4.0</td>
<td>64.5 ± 3.3</td>
<td>0.38 ± 0.08</td>
</tr>
<tr>
<td>E 69991 x IK 7610</td>
<td>32.8 ± 4.3</td>
<td>20.0 ± 5.4</td>
<td>67.2 ± 4.3</td>
<td>0.30 ± 0.10</td>
</tr>
<tr>
<td>E 69991 x SSS 2</td>
<td>39.1 ± 3.7</td>
<td>27.7 ± 3.9</td>
<td>60.9 ± 3.7</td>
<td>0.46 ± 0.09</td>
</tr>
<tr>
<td>N 10 x G. Kepandjen</td>
<td>30.7 ± 3.8</td>
<td>20.5 ± 4.2</td>
<td>69.3 ± 3.8</td>
<td>0.30 ± 0.08</td>
</tr>
<tr>
<td>N 13 x IK 7610</td>
<td>35.7 ± 8.7</td>
<td>24.6 ± 10.2</td>
<td>64.3 ± 8.7</td>
<td>0.42 ± 0.28</td>
</tr>
<tr>
<td>N 13 x IS 76216</td>
<td>43.0 ± 10.4</td>
<td>31.6 ± 11.0</td>
<td>57.0 ± 10.4</td>
<td>0.61 ± 0.32</td>
</tr>
<tr>
<td>N 14 x IK 7610</td>
<td>34.7 ± 3.8</td>
<td>24.0 ± 4.0</td>
<td>65.3 ± 3.8</td>
<td>0.37 ± 0.08</td>
</tr>
<tr>
<td>N 14 x IS 76216</td>
<td>37.8 ± 5.1</td>
<td>26.9 ± 5.6</td>
<td>62.2 ± 5.1</td>
<td>0.44 ± 0.15</td>
</tr>
<tr>
<td>NCo 376 x G. Kepandjen</td>
<td>29.7 ± 3.2</td>
<td>17.1 ± 3.7</td>
<td>70.3 ± 3.2</td>
<td>0.25 ± 0.07</td>
</tr>
<tr>
<td>NCo 376 x IS 76216</td>
<td>33.8 ± 5.1</td>
<td>22.8 ± 4.2</td>
<td>66.2 ± 5.1</td>
<td>0.35 ± 0.09</td>
</tr>
<tr>
<td>SP 716113 x IK 7610</td>
<td>37.0 ± 4.7</td>
<td>26.7 ± 5.6</td>
<td>63.0 ± 4.7</td>
<td>0.43 ± 0.14</td>
</tr>
<tr>
<td>SP 716113 x IS 76216</td>
<td>40.6 ± 6.9</td>
<td>31.7 ± 6.8</td>
<td>59.4 ± 6.9</td>
<td>0.56 ± 0.21</td>
</tr>
</tbody>
</table>

There were statistically highly significant differences between the 14 families for all characters (Tables 3 and 4) showing the presence of genetic variation in the population. The within family mean square was quite low compared to that of the between full-sib family and concur with those of commercial-type crosses (Badaloo 1997; Ramdoyal and Badaloo 1998). From the variance ratios, family effects were highest for Brix % cane, pol % dry matter, pol:fibre ratio, Brix % dry matter, fibre % dry matter and stalk diameter. However, variance ratio was relatively less pronounced for pol % cane and fibre % cane, showing that both the between and within family variation are important for the two characters.

Heritability estimates were moderately low for stalk number (0.39) compared to stalk diameter (0.75) (Table 3). Stalk number is therefore less likely to be predicted from the parents compared to stalk diameter. Among the cane quality characters, dry matter % cane had the lowest heritability (0.17) followed by fibre % cane (0.38), which may result from the relatively lower genotypic coefficient of variation (Table 3). Hence, dry matter content of the progenies cannot be predicted from the parental values. Brix and pol had high heritability such that these traits will respond positively to selection and offer opportunities for improvement by breeding.

The moderately high to high narrow sense heritability estimates may be a result of high genetic variance or low environmental variance or both and are in contrast to low to moderate estimates in commercial-type crosses (Ramdoyal and Badaloo 1998; Lawrence and Sunil 1997). Genetic improvement from current breeding stock is proving increasingly difficult and the use of wide crosses involving selected ancestral types for the introduction of new sources of variability is advocated (Bull and Glasziou 1963). Highest response to selection was observed for pol:fibre ratio, pol % cane, pol % dry matter, stalk number, Brix % cane and stalk diameter. The lowest expected genetic advance was for dry matter % cane, fibre % cane and fibre % dry matter. Generally, high genetic advance was associated with high heritability values. Thus, these traits provide good opportunity for further improvement.
Table 3 Components of variation, estimates of narrow-sense heritability and genetic advance for agro-morphological and cane quality characters, derived from the analysis of variance of the crosses

<table>
<thead>
<tr>
<th>Components of variation and genetic parameters</th>
<th>Stalk number</th>
<th>Stalk diameter</th>
<th>Brix</th>
<th>Pol</th>
<th>Fibre</th>
<th>Dry matter</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between family MS</td>
<td>1013.60 **</td>
<td>178.22 **</td>
<td>67.11 **</td>
<td>91.28 **</td>
<td>82.83 **</td>
<td>38.96 **</td>
<td>0.152 **</td>
</tr>
<tr>
<td>Within family MS</td>
<td>100.80</td>
<td>7.29</td>
<td>2.12</td>
<td>30.20</td>
<td>8.45</td>
<td>8.70</td>
<td>0.006</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>10.06</td>
<td>24.45</td>
<td>31.66</td>
<td>3.02</td>
<td>9.80</td>
<td>4.48</td>
<td>25.330</td>
</tr>
<tr>
<td>$\sigma^2_b$</td>
<td>24.43 ± 9.9</td>
<td>4.57 ± 0.017</td>
<td>1.74 ± 0.65</td>
<td>2.36 ± 0.86</td>
<td>1.99 ± 0.81</td>
<td>0.81 ± 0.14</td>
<td>0.04 ± 0.001</td>
</tr>
<tr>
<td>$\sigma^2_w$</td>
<td>100.80 ± 6.2</td>
<td>7.29 ± 0.004</td>
<td>2.12 ± 0.13</td>
<td>3.02 ± 1.87</td>
<td>8.45 ± 0.52</td>
<td>8.70 ± 0.18</td>
<td>0.0064 ± 0.0003</td>
</tr>
<tr>
<td>$V_g$</td>
<td>48.86 ± 19.8</td>
<td>9.16 ± 0.03</td>
<td>3.48 ± 1.3</td>
<td>4.72 ± 1.70</td>
<td>3.98 ± 1.60</td>
<td>1.62 ± 0.28</td>
<td>0.0078 ± 0.003</td>
</tr>
<tr>
<td>$V_e$</td>
<td>76.36</td>
<td>2.92</td>
<td>0.38</td>
<td>0.66</td>
<td>6.46</td>
<td>7.89</td>
<td>0.0025</td>
</tr>
<tr>
<td>$V_p$</td>
<td>125.23 ± 11.7</td>
<td>12.08 ± 0.01</td>
<td>3.86 ± 0.67</td>
<td>5.38 ± 2.1</td>
<td>10.44 ± 0.96</td>
<td>9.51 ± 0.23</td>
<td>0.0103 ± 0.005</td>
</tr>
<tr>
<td>Heritability</td>
<td>0.39 ± 0.03</td>
<td>0.75 ± 0.03</td>
<td>0.90 ± 0.03</td>
<td>0.88 ± 0.03</td>
<td>0.38 ± 0.03</td>
<td>0.17 ± 0.02</td>
<td>0.76 ± 0.02</td>
</tr>
<tr>
<td>Genotypic CV (%)</td>
<td>30.02</td>
<td>17.29</td>
<td>17.53</td>
<td>29.01</td>
<td>10.51</td>
<td>4.29</td>
<td>12.800</td>
</tr>
<tr>
<td>Environmental CV (%)</td>
<td>37.54</td>
<td>9.80</td>
<td>5.79</td>
<td>10.85</td>
<td>13.38</td>
<td>9.48</td>
<td>7.240</td>
</tr>
<tr>
<td>Genetic advance (% mean)</td>
<td>38.62</td>
<td>30.58</td>
<td>34.23</td>
<td>56.14</td>
<td>13.32</td>
<td>3.64</td>
<td>23.030</td>
</tr>
<tr>
<td>General mean</td>
<td>23.28</td>
<td>17.50</td>
<td>10.64</td>
<td>7.49</td>
<td>18.99</td>
<td>29.63</td>
<td>0.690</td>
</tr>
</tbody>
</table>

Tai et al. (1992), found additive genetic variance was more important than dominance genetic variance for Brix, sucrose content, juice purity and fibre content in commercial hybrids x S. spontaneum crosses. Selection was effective in improving juice purity while lowering fibre content. Genetic analysis of F1 populations derived from S. officinarum x S. barberi, S. robustum, S. spontaneum, commercial hybrids, indicated highest heritability values in S. spontaneum group (Bakshi Ram et al. 1992). For crosses which involved commercial hybrids and S. robustum, Rao and Rao (1977) obtained moderate to high narrow sense heritability for stalk number (0.52), stalk diameter (0.60) and Brix (0.58).

Phenotypic correlation coefficients calculated between pairs of characters, based on family means, indicated stalk number was negatively correlated with stalk diameter (Table 5) but positively correlated with fibre on both a fresh and dry weight basis, associations typical of S. spontaneum clones. Stalk number and fibre were negatively correlated with Brix and pol. These results concur with those of Jackson (1994) for commercial x S. spontaneum crosses. Stalk diameter showed a highly significant positive correlation with Brix % cane, pol % cane, pol % dry matter, pol:fibre ratio and purity while showing highly significant negative correlation with fibre % cane. Commercial varieties are derived from S. officinarum which carry the “sucrose genes” and are generally characterised by thick stalk diameter and low fibre content. Brix % cane and pol % cane were highly positively correlated and compare well with commercial-type crosses (Mamet et al. 1996). Pol (fresh and dry weight basis) was negatively correlated with fibre and tends to show that in the populations under study it would be difficult to increase pol % cane and fibre % cane concurrently.
**Table 4** Components of variation, estimates of narrow-sense heritability and genetic advance for cane quality characters on a dry weight basis, derived from the analysis of variance of the crosses

<table>
<thead>
<tr>
<th>Components of variation and genetic parameters</th>
<th>Brix % dry matter</th>
<th>Pol % dry matter</th>
<th>Fibre % dry matter</th>
<th>Pol:Fibre ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between family MS</td>
<td>791.48 **</td>
<td>1055.07 **</td>
<td>791.48 **</td>
<td>0.58 **</td>
</tr>
<tr>
<td>Within family MS</td>
<td>29.79</td>
<td>35.73</td>
<td>29.79</td>
<td>0.02</td>
</tr>
<tr>
<td>Variance ratio</td>
<td>26.57</td>
<td>29.53</td>
<td>26.57</td>
<td>29.00</td>
</tr>
<tr>
<td>$\sigma^2_w$</td>
<td>29.79 ± 1.84</td>
<td>35.73 ± 2.21</td>
<td>29.79 ± 1.84</td>
<td>0.02 ± 0.0010</td>
</tr>
<tr>
<td>$\sigma^2_b$</td>
<td>40.78 ± 14.90</td>
<td>54.56 ± 19.90</td>
<td>40.78 ± 14.90</td>
<td>0.02 ± 0.0100</td>
</tr>
<tr>
<td>Vp</td>
<td>9.40</td>
<td>8.45</td>
<td>9.40</td>
<td>0.01</td>
</tr>
<tr>
<td>Vp</td>
<td>50.18 ± 7.70</td>
<td>63.01 ± 10.20</td>
<td>50.18 ± 7.70</td>
<td>0.03 ± 0.0050</td>
</tr>
<tr>
<td>Heritability</td>
<td>0.81 ± 0.03</td>
<td>0.86 ± 0.03</td>
<td>0.81 ± 0.03</td>
<td>0.67 ± 0.0002</td>
</tr>
<tr>
<td>Genotypic CV (%)</td>
<td>14.84</td>
<td>29.16</td>
<td>10.00</td>
<td>34.49</td>
</tr>
<tr>
<td>Environmental CV (%)</td>
<td>7.13</td>
<td>11.48</td>
<td>4.82</td>
<td>24.39</td>
</tr>
<tr>
<td>Genetic advance (%)</td>
<td>27.48</td>
<td>55.52</td>
<td>18.52</td>
<td>58.31</td>
</tr>
<tr>
<td>General mean</td>
<td>43.02</td>
<td>25.33</td>
<td>63.85</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Table 5** Phenotypic correlation coefficients, based on a family basis, among agromorphological and quality characters

<table>
<thead>
<tr>
<th></th>
<th>Stalk diameter</th>
<th>Brix % cane</th>
<th>Pol % cane</th>
<th>Fibre % cane</th>
<th>Dry matter % cane</th>
<th>Pol % dry matter</th>
<th>Fibre % dry matter</th>
<th>Pol:Fibre ratio</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stalk number</td>
<td>-0.62 **</td>
<td>-0.50 *</td>
<td>-0.50 *</td>
<td>0.58 **</td>
<td>0.19</td>
<td>-0.53 *</td>
<td>0.54 *</td>
<td>-0.51 *</td>
<td>-0.47 *</td>
</tr>
<tr>
<td>Brix % cane</td>
<td></td>
<td>0.98</td>
<td>-0.75 **</td>
<td>0.21</td>
<td>0.98</td>
<td>-0.96 *</td>
<td>0.95</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>Pol % cane</td>
<td>0.74 **</td>
<td>0.72 **</td>
<td>-0.68 **</td>
<td>-0.68 **</td>
<td>0.19</td>
<td>-0.75 **</td>
<td>0.77 **</td>
<td>0.72 **</td>
<td>0.68 **</td>
</tr>
<tr>
<td>Fibre % cane</td>
<td>-0.71 **</td>
<td>-0.68 **</td>
<td>-0.68 **</td>
<td>-0.68 **</td>
<td>0.77 **</td>
<td>-0.75 **</td>
<td>0.95 **</td>
<td>0.91 **</td>
<td>0.91 **</td>
</tr>
<tr>
<td>Dry matter % cane</td>
<td></td>
<td>0.49 *</td>
<td>-0.83 **</td>
<td>0.90 **</td>
<td>-0.87 **</td>
<td>-0.61 **</td>
<td>-0.84 **</td>
<td>-0.84 **</td>
<td></td>
</tr>
<tr>
<td>Pol % dry matter</td>
<td></td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>-0.04</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre % dry matter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pol:Fibre ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.87 **</td>
<td></td>
</tr>
</tbody>
</table>

* 5% significance level
** 1% significance level

However, when the correlations were computed within each family, it was possible to identify families where weak or no negative correlations could be depicted between stalk number and diameter as exemplified in crosses N 14 x IS 76216 and E 69991 x IS 76216 (Table 6). Similarly pol % cane and fibre % cane were positively correlated in crosses N 14 x IK 7610 and E 69991 x SSS 2 and provide opportunities to select for F1 clones that combine the desirable traits of high pol % cane and fibre % cane.
Variation and inheritance of quantitative traits in commercial x S. spontaneum L crosses. MGH Badaloo and K Ramdoyal

Table 6 Phenotypic correlation coefficients based on individual values within each family, between some characters of interest

<table>
<thead>
<tr>
<th>Families</th>
<th>Stalk number v/s stalk diameter</th>
<th>Stalk diameter v/s pol % cane</th>
<th>Stalk number v/s fibre % cane</th>
<th>Pol % cane v/s fibre % cane</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 684 x IS 76216</td>
<td>-0.23</td>
<td>-0.14</td>
<td>-0.25</td>
<td>-0.20</td>
</tr>
<tr>
<td>D 684 x SSS 2</td>
<td>-0.09</td>
<td>0.14</td>
<td>0.03</td>
<td>-0.09</td>
</tr>
<tr>
<td>E 69991 x IK 7610</td>
<td>-0.19</td>
<td>0.06</td>
<td>0.23</td>
<td>0.16</td>
</tr>
<tr>
<td>E 69991 x IS 76216</td>
<td>0.14</td>
<td>0.02</td>
<td>0.34</td>
<td>0.18</td>
</tr>
<tr>
<td>E 69991 x SSS 2</td>
<td>-0.38</td>
<td>*</td>
<td>0.21</td>
<td>0.27</td>
</tr>
<tr>
<td>N10 x Kepandjen</td>
<td>0.13</td>
<td>-0.08</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>N13 x IK 7610</td>
<td>-0.09</td>
<td>0.27</td>
<td>0.03</td>
<td>-0.29</td>
</tr>
<tr>
<td>N13 x IS 76216</td>
<td>-0.48</td>
<td>**</td>
<td>-0.73</td>
<td>** -0.68 **</td>
</tr>
<tr>
<td>N14 X IK 7610</td>
<td>-0.32</td>
<td>-0.39</td>
<td>*</td>
<td>0.12</td>
</tr>
<tr>
<td>N14 X IS 76216</td>
<td>-0.02</td>
<td>0.45</td>
<td>**</td>
<td>-0.50 **</td>
</tr>
<tr>
<td>NCo 376 x Kepandjen</td>
<td>-0.11</td>
<td>-0.16</td>
<td>0.27</td>
<td>0.38                       **</td>
</tr>
<tr>
<td>NCo 376 x IS 76216</td>
<td>-0.11</td>
<td>-0.10</td>
<td>0.22</td>
<td>0.09</td>
</tr>
<tr>
<td>SP 716113 x IK 7610</td>
<td>-0.21</td>
<td>-0.05</td>
<td>0.27</td>
<td>0.04</td>
</tr>
<tr>
<td>SP 716113 x IS 76216</td>
<td>-0.30</td>
<td>0.32</td>
<td>0.47</td>
<td>** -0.54 **</td>
</tr>
</tbody>
</table>

* 5% significance level
** 1% significance level

There were highly significant correlations between the RANK and FREQ statistics for all bivariate combinations of characters involving fibre and pol (Table 7). In all cases, the correlation coefficients were negative (-0.76** and -0.70 **) as the lower the sum of rank, the higher the potential of the cross to produce genotypes that exceeded the set targets. Likewise for pol % dry matter and fibre % dry matter, negative correlations between FREQ and RANK were observed (-0.46 and -0.58*). In contrast stalk number and stalk diameter were not correlated in their joint prediction (r = 0.08 to -0.06) at various targets set, as indicated by the negative correlation between the two characters (Table 5). There were highly significant correlations between RANK and FREQ for pair-wise combinations of characters involving stalk number and dry matter % cane (-0.72** to -0.89**), stalk number and pol % cane (-0.56* to -0.59*) and stalk number and fibre % cane (-0.72** to -0.76**). In general, the two statistics were strongly correlated in their prediction of stalk number and fibre / dry matter % cane but moderately correlated for stalk number and pol % cane. Stalk diameter and fibre % cane were not correlated in their joint prediction (r = -0.16) at the set targets. Highest correlation coefficients between RANK and FREQ indicate that these statistics are robust enough to evaluate commercial x S. spontaneum crosses.

Commercial hybrids constitute a selected and adapted genetic stock that is easier to hybridise and provide quicker scope for progress (Ramdoyal and Badaloo 2002). Rigorous selection criteria should be applied during backcrossing when more genetic variability would be created by the segregation and recombination of genes and the breaking down of linkage between characters of interest and undesirable alleles. Furthermore, high sucrose, thick stalk diameter commercial hybrids should be favoured as the female parents in backcrossing to counteract the effects of linkage drag and to increase the efficiency of generating improved hybrid.
Table 7 Correlation coefficients between the sum of ranks (RANK) and the observed frequency (FREQ) of genotypes that exceed the set targets of two variates simultaneously

<table>
<thead>
<tr>
<th>Bivariate combinations and targets</th>
<th>Correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pol % cane</td>
<td>Fibre % cane</td>
</tr>
<tr>
<td>7.5</td>
<td>18</td>
</tr>
<tr>
<td>19</td>
<td>-0.76**</td>
</tr>
<tr>
<td>20</td>
<td>-0.70**</td>
</tr>
<tr>
<td>Pol % dry matter</td>
<td>Fibre % dry matter</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td>Stalk number</td>
<td>Stalk diameter</td>
</tr>
<tr>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td>Stalk number</td>
<td>Dry matter % cane</td>
</tr>
<tr>
<td>23</td>
<td>30</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Stalk number</td>
<td>Pol % cane</td>
</tr>
<tr>
<td>25</td>
<td>7.5</td>
</tr>
<tr>
<td>30</td>
<td>7.5</td>
</tr>
<tr>
<td>Stalk number</td>
<td>Fibre % cane</td>
</tr>
<tr>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>21</td>
<td>-0.74**</td>
</tr>
<tr>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>21</td>
<td>-0.72**</td>
</tr>
<tr>
<td>Stalk diameter</td>
<td>Fibre % cane</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

Significance levels 0.53 @ 5% and 0.66 @ 1%

CONCLUSION

Under local conditions asynchronous flowering between the wild species and the S. officinarum clones is the main obstacle to the basic interspecific hybridisation programme. The commercial x S. spontaneum strategy offers a sound alternative to exploit the genetic variation of the wild species (Tai et al. 1992), and to overcome to some extent the problems associated with shy flowering in nobles and low pollen fertility. Differences between crosses between commercial x S. spontaneum clones was of enough magnitude to allow breeding and selection for the characters of interest. Although negative associations were determined between pol and fibre and fibre and stalk diameter, it was possible to select families which offer possibilities to combine characters of interest for the production of improved parents and/or varieties.

ACKNOWLEDGEMENTS

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CHARACTERIZATION OF NATURAL ENVIRONMENTS FOR SUGARCANE FLOWERING ABILITY

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Mauritius Sugar Industry Research Institute

ABSTRACT

Sugarcane flowers naturally in Mauritius but the number of clones and flowering intensity vary between sites and years. The production of inflorescences, especially in the best varieties and elite clones has to be ensured for a successful plant improvement programme. While traditional breeding plots have been the major source of inflorescences for sugarcane breeding since the inception of the programme, a lack of inflorescences, particularly in the shy flowering clones has cropped up during the past recent years as a result of erratic flowering. Before embarking on the adoption of artificial induction, which is the case in many sugarcane breeding countries, natural environments were screened for their flowering ability. Flowering was followed in 21 trials planted at sites widely distributed over the island with the objective of identifying the one most favourable to this process and that could be adopted for planting new breeding plots. Characterization of the environments was based on an assessment of flowering intensity and the percentage of flowered varieties over three consecutive years. Flowering occurred at all sites but the percentage of flowered varieties and the flowering intensity differed widely between years for the same environment and between environments for the same year. The absence of weather extremes, namely lack of rainfall and occurrence of temperatures above 31°C during the very sensible induction/initiation phases in the South and East sectors were most conducive to flowering. The best site (Deux Bras 4099) was identified and a breeding plot established. A subsequent follow-up of flowering revealed that certain varieties flowered at this site only and not in the traditional breeding plots, confirming its higher potential for sugarcane flowering compared to those where traditional breeding plots are located.

Keywords: Inflorescence, initiation, crossing, weather conditions.

INTRODUCTION

New commercial sugarcane varieties are usually produced through crossing of parental clones according to the objectives set within the sugarcane improvement programme. In many countries, due to low and poor flowering ability of the sugarcane, breeders very often resort to artificial induction as a means to initiate and promote flowering in non- and poor flowering clones of interest. In Mauritius, traditional breeding plots have always been the main source of inflorescence for crossing.

Flowering in the sugarcane is a complex physiological process consisting of multiple stages of development, each stage having specific environmental and physiological requirements (Julien 1972). Thus, if the specific day length, temperature and moisture requirements are not satisfied, flowering is inhibited or the intensity is reduced. Under natural conditions, day length being fixed at any given latitude and date (Moore 1987), it is essentially the location (altitude), temperature (Coleman 1969), moisture stress and the nutrition level (Gosnell 1973 and Moore 1987) that affect the timing and intensity of flowering.

For induction to take place sugarcane stalks must be physiologically mature or have reached the ‘ripeness to flower’ stage (Coleman 1969). It has been found that this stage corresponds to an optimum number of internodes that coincide with the end of the juvenile phase and the photo-inductive stage, generally the development of 2 - 4 mature internodes at the base of the stalks (Coleman 1969 and Moore 1987).

Each stage of the flowering process is temperature dependent as it involves biochemical processes (Coleman 1969). The daytime and nighttime optimal temperatures for flower initiation and
development have been reported to be around 28°C (Clements and Awada 1967) and 23°C respectively. Intermittent occurrences of night temperatures below 18°C during the period of floral induction have been reported to reduce flowering intensity and / or delay emergence (Coleman 1963 and Gosnell 1973). Frequent occurrences of daytime temperatures exceeding 31°C have been reported to severely reduce flowering intensity or delay emergence (Ellis et al. 1967; Nuss and Brett 1977). The latter can be due to a true temperature effect or indirectly related to the resulting water stress.

Soil moisture availability is another environmental factor that can adversely affect flowering (Pereira et al. 1983). In areas where photoperiod and temperature seldom inhibit flowering, variations in intensity of flowering between years resulted from differences in annual rainfall. The availability of soil moisture in relation to flowering lies in the production of photosyntates, which go into the synthesis of a flowering hormone and in its translocation to the apex (Lang 1965). In the final stage of the flowering process, sufficient moisture is needed for the elongation of the stalk of the inflorescence and its emergence.

The nutritional regime has also been shown to interfere with flowering. For maximum flowering, sugarcane must be growing vigorously (Moore 1987). Increasing levels of nitrogen have consistently resulted in reduced flowering intensity (Clements and Awada 1967; Gosnell 1973 and Moore 1987). The extent to which flowering is affected depends on the clone, the age of the crop, and the availability of water. The younger the crop, the lower the amount of nitrogen required for inhibiting flowering.

It has been reported that elevation could be used to promote flower induction and enhance flower development in the sugarcane (Arceneaux, 1954 and Ellis et al. 1967). They concluded that the decrease in the daily maximum temperature, linked with increasing altitudes, was the controlling factor for extensive flowering. Increased rainfall and cloudiness could serve as supplementary factors to depress maximum temperatures.

In Mauritius, most natural environments do possess the potential for successful induction of flowering. However, not all will favour flowering to the extent required for breeding purposes and without a high annual variability. *Saccharum spontaneum* is the first to flower at around mid-April. In the commercial hybrids, flowering starts around mid-May to proceed to mid-July for the late flowering ones and the noble canes. Crosses are only performed during the flowering period and in the past recent years a lack of inflorescences in shy flowering clones has been felt following poor and erratic flowering in traditional breeding plots. Consequently, this has limited the use of desired parental clones for crossing. This reduction in flowering ability could be due to prevailing environmental factors being no longer conducive to flowering at locations where traditional breeding plots are sited. However, prior to commissioning costly facilities for artificial induction it has been considered more convenient to search for locations with environmental conditions more conducive to flowering compared to those of the traditional breeding plots.

**MATERIALS AND METHODS**

**Description of trials**

Twenty-seven on-going variety trials located at different altitudes and experiencing a wide range of rainfall (Table 1) and temperature regimes were surveyed for their flowering potential in 1998, 1999 and 2000. The trials were planted in a randomised block design with three replicates and each plot consisted of four rows 10 m long. Each trial comprised 20 - 25 commercial hybrids inclusive of five standard varieties at most. While the varieties under test were planted in a maximum of four trials, the standard varieties R 570, M 1658/78, M 3035/66 and M 555/60 were present in 21, 19, 16 and 14 trials respectively.

All trials were harvested in July to ensure that normal growth of the plants could take place so that at the floral induction period, they were physiologically mature to respond to the flowering stimulus.


**Table 1** Details of trials

<table>
<thead>
<tr>
<th>Sector</th>
<th>Trial No</th>
<th>Site / Field no.</th>
<th>Altitude (m)</th>
<th>Annual rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>1</td>
<td>Sottise 99</td>
<td>20</td>
<td>1 250</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Mon Rocher 76</td>
<td>85</td>
<td>1 550</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Mon Rocher 56</td>
<td>90</td>
<td>1 550</td>
</tr>
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<td></td>
<td>4</td>
<td>Bon Espoir 87</td>
<td>120</td>
<td>1 700</td>
</tr>
<tr>
<td>East</td>
<td>5</td>
<td>La Retraite 107</td>
<td>45</td>
<td>1 800</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>La Plaine 137</td>
<td>60</td>
<td>1 800</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>La Retraite 120</td>
<td>100</td>
<td>2 000</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Sans Souci 1634</td>
<td>315</td>
<td>3 800</td>
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<td></td>
<td>9</td>
<td>St Julien 2401</td>
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<td>Benares 5101</td>
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<td>2 300</td>
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<td>14</td>
<td>New Grove 2019</td>
<td>225</td>
<td>2 750</td>
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<tr>
<td></td>
<td>15</td>
<td>Jolibois 45</td>
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<td>2 700</td>
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<td>16</td>
<td>Union Park 3242</td>
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<td>3 075</td>
</tr>
<tr>
<td>West</td>
<td>17</td>
<td>Tamarin 5505</td>
<td>70</td>
<td>1 200</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Mon Repos 3205</td>
<td>130</td>
<td>1 000</td>
</tr>
<tr>
<td>South</td>
<td>19</td>
<td>Valetta 65</td>
<td>460</td>
<td>3 350</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Cote D’or 1283</td>
<td>455</td>
<td>3 200</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Bonne veine 34</td>
<td>480</td>
<td>2 900</td>
</tr>
</tbody>
</table>

**Flowering assessment**

The number of varieties that flowered was surveyed and presented as the % of the total number of varieties planted in each trial. The number of flowered stalks and the total number of tillers in the two middle rows of each plot were counted in June and July. The number of flowered stalks also included those that were in the flag stage. Flowering intensity for each variety was expressed as the percentage of flowered stalks out of the total number of tillers of each plot. The mean flowering intensity of each trial was the average of the flowering intensity of all varieties that flowered.

**Meteorological data**

Daily rainfall, minimum, and maximum temperatures recorded during the induction and flower development period as from mid-February to end March from meteorological stations on-site or in the vicinity of the trials were analyzed in relation to the flowering data collected.

**New breeding plot**

In light of the results obtained, one breeding plot was implemented at the site identified as the best for flowering ability and included clones recognized as non- or shy-flowering. The objectives were to confirm the suitability of the environment to induce floral development and to produce inflorescences for crossing purposes. Flowering was assessed and compared for those varieties that existed in the traditional breeding plots sited at Réduit and Pamplemousses.

RESULTS AND DISCUSSION

Results pertaining to only 21 trials are presented as the other six were lost accidentally or the field uprooted for replantation during the experimentation period. Moreover, though surveys were carried out over three years, results for 1999 have not been included because of the very severe drought that adversely affected flowering all over the island through induced severe soil moisture and heat stresses (MSIRI 1998; 1999; 2000).

Meteorological conditions

Rainfall

In 1998, the above normal rainfall recorded in February in most regions compensated fully the deficit of January. The month of March was characterized by below normal rainfall with only 72% of the long-term mean for the island. Apart from the West where only 51 mm of rainfall were recorded during this month but where the crop was irrigated, the deficit was not considered severe enough to be detrimental to floral induction and development. During the induction and critical floral development phase period of 2000, rainfall was normal all over the island.

Temperature

Both maximum and minimum temperatures were within acceptable limits for induction to take place in all sectors irrespective of year except in some regions of the North and West where maximum temperatures exceeded 31°C on some days. In 1998 maximum temperature exceeded 31°C on 13 days in March in the North and on 5 days in February and 10 days in March in the West. Minimum temperature was lower than 18°C on three days in the Centre only. In 2000, both maximum and minimum temperatures were within the range 18°C to 31°C in all sectors.

"Ripeness to flower"

The ability of a sugarcane stalk to perceive and respond to inductive photoperiods depends on its physiological state i.e its "ripeness to flower". Results for 1998 and 2000 are presented in Table 2 for the percentage of varieties with mature phytomers (%) equal or greater than 2 and 4, counted at each site. For both years at all sites, all varieties had varying number of stalks with more than 2 and also 4 mature phytomers. Thus all varieties were rated physiologically mature for induction.

Assessment of the number of flowering varieties and flowering intensity

The results of the percentage of varieties that flowered and the mean and the range of flowering intensity are presented in Table 3. Sector-wise the following comments are warranted.

North

The percentage of flowering varieties varied from 10% - 56% across sites in 1998 and from 25% - 68% in 2000 to give averages of 33.8% and 46.3% respectively. Mean flowering intensity of trials ranged from 5.4% to 18.7% in 1998 and from 3.2% to 10.7% in 2000. The overall averages were 12.7% and 7.6%. Thus more varieties responded to the flowering stimulus in 2000 but a lower percentage of stalks flowered compared to 1998.

While it remains difficult to explain the better response of the higher number of varieties to the flowering stimulus in 2000, the lower intensity in flowered varieties is attributed to a lower number of stalks being mature enough to perceive the stimulus. Indeed the percentage number of stalks of flowering varieties with more than 2 fully formed phytomers, was only 32.6% to 59.5% in 2000 compared to the range 98.8% to 100% in 1998.
East

Generally, flowering was favourable in this sector. Overall for the five trials, 73.4% and 81.6% of the varieties flowered in 1998 and in 2000 for respective mean flowering intensities of 32.9% and 27.5%. The % varieties that flowered ranged from 56% to 84% and 64% to 92% for 1998 and 2000 respectively. Flowering intensity varied from 20.4% to 58.4% in 1998 and 13.8% to 49.6% in 2000. Flowering intensity reached 100% in some varieties in a few sites in both years. The good aptitude of this sector for flowering is attributed to the absence of weather extremes, known to be detrimental to the process, and which also contributed to normal growth that led to physiological maturity of a significantly higher percentage of the stalks in all varieties.

South

Considering the two years, conditions in the South sector were even more favourable to flowering than in the East. The number of flowered varieties varied from 68% to 96% in 1998 and from 84% to 96% in 2000 for means of 77.4% and 88.9% for all trials surveyed in that sector. The mean intensity for varieties that flowered was 32.7% and 32.3% for the two years. The maximum of 100% flowering was attained in two trials in some varieties in 1998. In this sector also, the good performance was attributed to the mild climate with an absence of water stress and temperature extremes, detrimental to flowering. The highest number of varieties flowered in trial 11 (Deux Bras 4099) and reached 96% for both years while the best mean flowering intensity was also observed in the same trial with 65.1% and 59.4% in 1998 and 2000 respectively. This site was identified as the one most favourable for flowering of sugarcane among all those surveyed.

<table>
<thead>
<tr>
<th>Sector</th>
<th>% mature stalks</th>
<th>1998</th>
<th>2000</th>
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<td>N &gt; 4</td>
<td>N &gt; 2</td>
</tr>
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<td>99.0</td>
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<td>63.8</td>
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<td>87.6</td>
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<td>89.7</td>
<td>79.2</td>
<td>61.8</td>
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<td>97.6</td>
<td>80.3</td>
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<tr>
<td>21</td>
<td>89.7</td>
<td>66.4</td>
<td>90.6</td>
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</tbody>
</table>

N = Number of fully formed phytomers

183
Table 3 Percentage of flowered varieties, mean and range of flowering intensity in 21 trials

<table>
<thead>
<tr>
<th>Sector</th>
<th>Trial no.</th>
<th>Flowered varieties %</th>
<th>Flowering Intensity (%)</th>
<th>Flowered varieties %</th>
<th>Flowering Intensity (%)</th>
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<td>1998</td>
<td>2000</td>
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<tr>
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<td>Range</td>
<td>Mean</td>
<td>Range</td>
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<td>45</td>
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<td>24.7</td>
<td>1.0 - 100.0</td>
<td>80</td>
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<td>33.4</td>
<td>1.1 - 100.0</td>
<td>92</td>
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<td>East</td>
<td>7</td>
<td>84</td>
<td>58.4</td>
<td>1.7 - 100.0</td>
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<tr>
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<td>2.2 - 93.8</td>
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<td>20.4</td>
<td>1.5 - 97.2</td>
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<td>81.6</td>
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<td>35.7</td>
<td>1.6 - 100.0</td>
<td>88</td>
</tr>
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<td>1.0 - 63.5</td>
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<td>88</td>
<td>55</td>
<td>7.5 - 100.0</td>
<td>92</td>
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</tr>
<tr>
<td>Overall</td>
<td>Mean</td>
<td>68</td>
<td>31.3</td>
<td>77.1</td>
<td>25.9</td>
</tr>
</tbody>
</table>

**West**

The West sector comprised only two irrigated trials where flowering was among the best recorded for both years. The number of varieties that flowered was 74% and 90% with mean intensities of 49.5% and 26.5% for 1998 and 2000 respectively. These results are contradictory to those obtained in the other sectors. The lower response observed in 1998 is attributed to the high temperatures which prevailed during this year being non-conducive to flowering for some of the varieties. This sector is usually characterised as a low rainfall area and flowering depends heavily on the supply of irrigation. Since the latter cannot be guaranteed to ensure absence of soil moisture and heat stresses, breeding plots cannot be implanted in this zone.

**Centre**

In the Centre results were generally comparable to those obtained in the South. The mean number of flowering varieties varied between 72% to 88% and 56% to 92% for overall means of 78.7% and
74.7% for 1998 and 2000. Flowering intensity ranged between 26.1% and 51.2% for an average of 37.9% in 1998 while in 2000, intensity varied between 16.2% and 46%, average of 32.1%.

Rainfall in this sector was not deficient and maximum temperatures were always below the critical 31°C. Minimum temperatures dropped below 18°C on only three days during the initiation phase in 1998. However sites in this sector, despite their potential for flowering, cannot be retained for planting breeding plots because of the relatively colder temperatures experienced during the late floral development phase during the month of April. The long-term minimum temperature of around 18.6°C during this month in the Centre is unfavourable for the production of fertile pollen. This process requires a temperature higher than 21°C (Brett 1951 and Berding 1981).

Flowering ability and altitude

Many researchers have made extensive use of altitude as an aid to flower induction of the sugarcane and since the trials spanned a range of altitudes, the relationship of the latter to flowering ability was looked into. The trials surveyed covered altitudes of 20 m to 480 m above sea level. A low but positive correlation was obtained between altitude and both mean flowering intensity and the percentage of varieties that flowered with a slightly stronger relationship between altitude and the mean percentage of flowering varieties from the 1998 survey. This could be due to the indirect effect of eliminating soil moisture stress and/or high temperature extremes as postulated by Ellis et al. (1967) rather than a true altitude effect. Otherwise altitude did not appear to have any direct incidence on flowering in Mauritius.

Table 4 Flowering intensity of standard varieties R 570 and M 3035/66

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</tr>
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<td>-</td>
</tr>
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</tr>
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<td>0</td>
</tr>
<tr>
<td>4</td>
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</tr>
<tr>
<td>East</td>
<td></td>
<td></td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
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<td>21</td>
<td>0</td>
<td>0</td>
<td>8</td>
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</table>

Assessment based on standard varieties

Since the varieties planted in the trials were not common to all but to a maximum of four, a further evaluation of the sites was done on the basis of flowering of the two most common standards. Variety R 570 was present in all trials and M 3035/66 in 16 of them. Variety R 570 flowered at 8 and 13 sites while M 3035/66 flowered at 12 and 13 sites in 1998 and 2000 respectively. For both varieties and over the two years, the highest flowering intensity (Table 4) was obtained in trial 11 (Deux Bras 4099)
in both standards. This confirms the higher potential of this site for flowering of the sugarcane under natural conditions.

**Assessment of new breeding plot at Deux Bras**

In 2001 one breeding plot was planted at Deux Bras 4099, the site identified as most conducive to flowering to further confirm the results obtained previously in the study. A comparison of varieties common to the traditional breeding plots at Reduit and Pamplemousses was made during the flowering season of 2002. Results indicated that initiation and flowering occurred in certain varieties (M 202/46, M 376/64 and M 907/61) only in the new breeding plot and not in the traditional ones.

**CONCLUSION**

In Mauritius, photoperiod is not a limiting factor to induction of flowering in the sugarcane as exemplified by the ability of at least some of the varieties to produce tassels all over the island in all the trials surveyed. Altitude also did not have direct consequences on induction but slightly regulated flowering intensity through the rainfall and temperature regimes. Generally maximum and minimum temperatures also were within limits except for a few locations and for short periods only. However weather variability through a combination of soil moisture stress and high daily temperatures in some years can affect both induction and flowering intensity. The South sector followed by the East were the two sectors most favourable for induction and flowering intensity as weather extremes detrimental to the flowering process are rarely encountered. The best location (Deux Bras 4099) was identified in the South and a breeding plot subsequently planted at this site. A follow-up of flowering confirmed the potential of the site for production of inflorescences for crossing purposes.

**REFERENCES**


IRRIGATION, DEROCKING AND MECHANIZATION FOR SUSTAINABLE SUGAR CANE PRODUCTION

I Jhoty and S Ramasamy
Mauritius Sugar Industry Research Institute

ABSTRACT

To overcome present and future challenges, the main stakeholders of the sugar cane industry have embarked on the implementation of measures that will allow business operation with reduced cost of production and ensure sustainable sugar cane production. Three key field measures have been clearly recognized: irrigation, derocking and mechanization. To appraise the contribution of these measures to satisfy the set objective on a national scale, the Mauritius Sugar Industry Research Institute has undertaken studies on each of them. About 19,000 ha of cane land have been identified that could further benefit from intensive irrigation to increase production if water was made available. Furthermore, use of more efficient irrigation systems would also increase cane yield. These actions, if implemented, could bring an additional production of sugar cane of the order of 10 to 15%. Derocking, which is essential to facilitate irrigation practices and mechanization of cultural operations, was moderately to highly intensive on miller-corporate-planters’ land, but was not so on large/small-planters’ land. Some 8900 ha of large/small-planters’ land would need intensive derocking and other land planning measures to allow mechanized cultural practices, and installation of more efficient irrigation systems where necessary. About 1460 ha presently under rock piles could be freed and thus contribute to increased production. Based on the suitability of land for mechanization, about 54,250 ha of cane land could be totally mechanized, whereas some 11,420 ha could be partially mechanized. Some 11,840 ha of cane land would hardly be suitable to mechanized cultural practices and could therefore, in the event of non-profitable sugar production on these areas, be released for other crops as well as other types of land development. While more cane land has been targeted for conversion to other uses in the next three to five years, the increase in production with irrigation, derocking and mechanization is expected to offset the likely reduction in total sugar cane production as a result of the land conversion. Large/small-planters should imperatively embark on the implementation of these measures, and injudicious conversion of prime agricultural sugar cane land should be discouraged to ensure increased and sustainable sugar cane production.

Keywords: cost efficiency, increased production, irrigation systems, derocking levels, land planning, mechanization suitability.

INTRODUCTION

The liberalisation of trade and the precariousness of preferential sugar prices have led the sugar cane industry in Mauritius, and also elsewhere, to face tough challenges for economic survival. Innovation and mechanization are needed to enable the industry to operate with reduced cost of production and sustainability. While many measures are being implemented to these ends, three of them, namely irrigation, derocking and mechanization of cultural practices, have clearly been identified at field level to contribute to the achievement of the objectives. Each of these measures has recently been the focus of studies at the Mauritius Sugar Industry Research Institute (MSIRI) and their findings have been published as MSIRI Occasional Reports (Jhoty, et al. 2001(a), (b) and 2002).

The main objectives of the studies were:

(i) to assess the current development of irrigation, derocking and mechanization, within the perspective of strategic planning;

(ii) to produce relevant maps to show the geographical distribution of:

(a) irrigation systems in use,

(b) different levels of derocking and

(c) the suitability of cane lands for mechanization.
This paper presents some main findings of the studies and discusses their impact on the Mauritian sugar cane industry.

**MATERIALS AND METHODS**

**Data collection**

Miller-/corporate-planters (sugar estates and planters owning more than 300 ha) provided data on irrigation, derocking and mechanization for individual field according to data source lists generated from the Land Index database. Specifically for irrigation, data were directly collected from the large-/medium-planters (owning more than 10 ha), and from the Irrigation Authority for the small-planters (owning less than 10 ha). Derocking levels on cane lands belonging to large-/medium-planters and small-planters were derived from aerial photographs of 1997, 1998 and 1999. The Land Resources and Agricultural Suitability Map of Mauritius (FAO and MSIRI, 1973) was referred to for determining the mechanization suitability of land belonging to large-/medium-planters and small-planters. After proper verification, all data were subsequently incorporated in the Land Index database. The main irrigation systems and sub-systems found are shown in Table 1.

**Table 1 Main irrigation systems and sub-systems**

<table>
<thead>
<tr>
<th>Main system</th>
<th>Sub-system</th>
<th>Irrigation equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>High-pressure</td>
<td>Target Master, Big Gun, Boom-o-Rain, Travelling Hose</td>
</tr>
<tr>
<td>Medium-pressure</td>
<td></td>
<td>Centre Pivot, Dragline</td>
</tr>
<tr>
<td>Drip</td>
<td>Wild flooding</td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>Improved surface</td>
<td>Siphon, Furrow, Gatedpipe, Layflat</td>
</tr>
</tbody>
</table>

The levels of derocking that were classified are as follows:

- **Level 1.** high intensity of derocking, including fine derocking (rocks of 8–10 cm in size removed), free of surface rock piles;
- **Level 2.** high intensity of derocking, excluding fine derocking (rocks of size 20 cm present and including non-rocky soils), free of surface rock piles;
- **Level 3.** moderate to high intensity of derocking, with very few to few scattered surface rock piles, less than 1% of area occupied by rock piles;
- **Level 4.** low to moderate intensity of derocking, with moderate density of surface rock piles, 1–5% of area occupied by rock piles;
- **Level 5.** low intensity of derocking, with high density of surface rock piles, 5–18% of area occupied by rock piles.

The suitability classes of land for mechanization were defined as follows:

- **M1** land suitable for full mechanization, land planning measures have been implemented (physical constraints overcome);
- **M2** land suitable for full mechanization, land planning measures are in progress or required (constraints: drains and rocky soils);
- **M3** land suitable for part to full mechanization, land planning measures are in progress or required (constraints: drains and rocky to very rocky soils);
- **M4** land suitable for part mechanization, excluding mechanized harvest, land planning measures are required (constraints: slopes, drains and very rocky soils);
- **M5** land not suitable at all for mechanization (constraints: steep slopes, drains and very rocky soils).
Land Index Database

The Land Index Database is managed within a geographic information system and consists of the physical, edaphic and agronomic data of each sugar cane field in Mauritius, including data on land suitability (Devil and Lim Shin Chong, 1984). It spans data for the three categories of planters: miller/corporate-planters, large-/medium-planters and small-planters.

GIS maps

Manually drafted maps were digitized and processed within MapInfo. The digitized output maps were geo-referenced to the local grid system as used on the published topographical maps of Mauritius at scale 1:25 000.

RESULTS AND DISCUSSION

Irrigation

As at 2000, irrigation was practised on 22% of land under sugar cane, mostly in the dry areas of the north, west and east. The irrigated areas for miller/corporate-planters represented about 28% of their total cane land, for large-planters 17% and for small-planters 8% (Table 2).

Table 2 Area irrigated under different systems for each category of planter

<table>
<thead>
<tr>
<th>Main irrigation system</th>
<th>Irrigation sub-system / type</th>
<th>Area (ha)</th>
<th>MCP*</th>
<th>LP / MP*</th>
<th>SP*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>High-pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Big gun, Target Master,</td>
<td>5,887</td>
<td>250</td>
<td>798</td>
<td></td>
<td>6,935</td>
</tr>
<tr>
<td></td>
<td>Boom-o-Rain, Travelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sprinkler (Hose reel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium-pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Centre Pivot, Dragline</td>
<td>5,839</td>
<td>623</td>
<td>174</td>
<td></td>
<td>6,636</td>
</tr>
<tr>
<td>Drip</td>
<td></td>
<td>1,052</td>
<td>93</td>
<td>302</td>
<td></td>
<td>1,447</td>
</tr>
<tr>
<td>Surface</td>
<td>Wild flooding, Improved</td>
<td>1,141</td>
<td>1,171</td>
<td>-</td>
<td></td>
<td>2,312</td>
</tr>
<tr>
<td></td>
<td>surface (Siphon, Furrow,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gatedpipe, Layflat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Area (ha)</td>
<td></td>
<td>13,920</td>
<td>2,137</td>
<td>1,274</td>
<td></td>
<td>17,331</td>
</tr>
<tr>
<td>% of area under cane</td>
<td></td>
<td>28</td>
<td>17</td>
<td>8</td>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

* - MCP = Miller-/corporate-planters; LP/MP = Large-/medium-planters; SP = Small-planters

The high pressure overhead irrigation systems (big gun, boom-o-rain, target master and hose reel) were the most widespread, covering 40% of the total irrigated areas. The two medium pressure overhead systems, centre pivot and dragline, occupied 39% of the total irrigated areas. In the past years, the centre pivot and dragline systems have been increasingly adopted as they are more efficient in terms of water use and costs (Monty, 2000; Teeluck, 1998). The drip irrigation system, introduced in Mauritius in the 1970’s, accounted for about 8% of the total irrigated areas. The system's high initial capital outlay coupled with high demanding management inputs are, however, restricting its further expansion. Surface irrigation was practised on about 13% of the total irrigated areas, the main type being wild flooding. In view of its low application efficiency, resulting from high water losses, surface irrigation was being less and less practised on miller/corporate-planters' land. The proportion of area irrigated by the system has declined since 1973.

About 77% of irrigated areas were found within the zone receiving less than 1500 mm mean annual rainfall, and about 20% within the zone of 1500 to 2000 mm mean annual rainfall. Within these two rainfall zones, about 19 000 ha, inclusive of the 3500 ha for the Northern Plain Phase II Irrigation
Irrigation, derocking and mechanization for sustainable sugar cane production. *I Jhoty and S Ramasamy*

Scheme, were identified as requiring irrigation. It is estimated that between 50 000 and 60 000 tonnes of sugar (10–12% of actual production) could be produced from the 19 000 ha if they were irrigated.

**Derocking**

About 54 507 ha of cane land, i.e. 70% of the total cane area, are of the rocky and stony soils. Of this cane area, 25.2%, i.e. 13 731 ha, has undergone thorough and fine derocking (derocking level 1) with complete removal of rock piles on the surface (Table 3). Miller-/corporate-planters own 95% of the areas of derocking level 1 and large-/medium-/small-planters own 5%. The area is suitable for mechanized cultural practices as land planning measures have also been completed.

**Table 3 Area distribution of derocking levels by category of planters**

<table>
<thead>
<tr>
<th>Level of derocking</th>
<th>Miller / Corporate planters</th>
<th>Large / Medium / Small planters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>%</td>
<td>Area (ha)</td>
</tr>
<tr>
<td>Level 1</td>
<td>13,102</td>
<td>39.2</td>
<td>629</td>
</tr>
<tr>
<td>Level 2</td>
<td>9,304</td>
<td>27.8</td>
<td>8,084</td>
</tr>
<tr>
<td>Level 3</td>
<td>1,978</td>
<td>5.9</td>
<td>3,428</td>
</tr>
<tr>
<td>Level 4</td>
<td>2,889</td>
<td>8.6</td>
<td>4,707</td>
</tr>
<tr>
<td>Level 5</td>
<td>6,179</td>
<td>18.5</td>
<td>4,207</td>
</tr>
<tr>
<td>Total</td>
<td>33,452</td>
<td>100.0</td>
<td>21,055</td>
</tr>
</tbody>
</table>

Areas of derocking level 2 amount to 17 388 ha, i.e. 31.9% of the total rocky and stony cane land, and have undergone intensive derocking and removal of surface rock piles but not fine derocking. Areas where derocking intensity has been high to moderate and with very few to few scattered rock piles remaining on the surface, derocking level 3, represent about 9.9% (5406 ha) of the rocky/stony cane land. In these areas, mechanical cane loading is possible, but thorough and fine derocking and other land planning measures are required to allow mechanical harvesting. Areas with low to moderate intensity of derocking, derocking level 4, and areas with low intensity of derocking, derocking level 5, total 7 596 ha and 10 386 ha, respectively. Rock piles on the surface are of moderate density, i.e. 5 to 12 per 10 ha, in the areas of derocking level 4, and are of high intensity, i.e. 13 to 35 per 10 ha, in the areas of derocking level 5. In the combined areas of derocking levels 4 and 5, thorough and fine derocking and land planning measures are required to render the areas suitable for mechanization, though in some places mechanized harvesting will be partly possible.

About 8 900 ha, i.e. 42.4%, of large-/medium- and small-planters cane lands need intensive derocking, including fine derocking and removal of surface rock piles, as compared to 27.1% for miller-/corporate-planters. It is estimated that thorough derocking, fine derocking and carting away surface rock piles would entail the displacement of 58 to 101 million tonnes of rocks and stones from fields. From the removal of surface rock piles, an area of 1460 ha could be freed and contribute to an additional sugar production of about 12 000 tonnes.

**Mechanization suitability**

Land suitable for full mechanization, whereby land planning measures have been implemented, class M1, represents 27% of the total area under cane, i.e. 20 495 ha (Figure 1). It is found in all climatic zones and consists of almost rock-free soils (33%) and rocky soils (67%).

Another 22% of the total area under cane, 17 253 ha of class M2, is also suitable for full mechanization but requires fine derocking and land planning measures. The soils and topography of land in this class are similar to those in class M1, however, rock free soils represent 26% of the land and rocky soils 74%. Areas suitable for part to full mechanization, suitability class M3, represent 25% of the total area under cane. The main constraints to mechanization are inappropriate field layout, drains and rocky soils. Rock-free soils represent 28% of the areas and rocky soils 72%. Costs of fine derocking and land planning measures are generally moderate to high in the areas of class M3. Land suitable for part mechanization, excluding mechanized harvest, class M4, comprising 11% of the total area under cane, are all of rocky and stony soils and are situated in all climatic zones. Intensive measures are required
to overcome the main constraints of inappropriate field layout, drains and, above all, the high degree of soil rockiness. About 11 840 ha, 15% of the total cane land, are not suitable at all for mechanized cultural operations, class M5. The main constraints are steep slopes, presence of deep drains, and very rocky soils.

Figure 1 Percentage area of mechanization suitability classes

Some 54 250 ha of cane land, i.e. 70% of the total cane area, are suitable for full mechanization. Land suitable for part mechanization, which excludes mechanized harvesting, amounts to about 11 420 ha, i.e. 15% of the total cane area, whereas land totally unsuitable for mechanization (marginal land) amounts to about 11 840 ha, i.e. 15% of the total cane area. In the event there is need for conversion of cane land to other uses, the marginal land should be given priority for such operations.

Impact of irrigation, derocking and mechanization

Irrigation increases yield and ensures sustainability of cane production. It is mainly required in the subhumid and some parts of the humid zones. An analysis of isohyets for periods of thirty years (1931-1960, 1950-1979,1961-1990) has shown that rainfall amounts have annually decreased by up to 200 mm in the coastal areas of the north and west of Mauritius. In localised areas of the central plateau, a marked rainfall diminution has also been observed. If this trend persists and global climate change contributes to a rise in temperature (Cheeroo-Nayamuth and Nayamuth, 1999), there will be increased needs for irrigation. Hence, irrigation and provision for storage of water should seriously be considered. The construction of the Midlands Dam to provide water for irrigation in the north is already a positive measure towards this end, but should be supplemented by the construction of other smaller dams in predetermined areas to satisfy the demand for irrigation.

Derocking not only enables to provide a good soil medium for sugar cane cultivation but also facilitates the installation of irrigation systems, increases machine efficiency, and avoids the breakage of implements during mechanized operations. In the present context of mechanization, intensive and fine derocking together with other land planning measures are vital to ensure the success of mechanization. Planters of the corporate sector have carried out intensive and fine derocking on a large proportion of their land. It is imperative for the other groups of planters, who are lagging behind with this programme, that they too should accelerate the process. Planters may not only benefit soft loans from the Bank of Mauritius for derocking, but may also recoup substantial cost of derocking from the sale of rocks.

The main objectives of mechanized cultural practices, including harvesting, are to reduce cost of production and allow prompt and timely operations. However, for efficiency and success of mechanized operations certain particular land planning measures such as fine derocking, land levelling, redesign of drains and roads and longer cane rows should be implemented. Presently, less than 25% of
the total area under cane cultivation are available for full mechanization. The objective is to attain, within five years, about 84% of the total cane area for full and partial mechanization.

**Table 4** Benefits of irrigation, derocking and mechanization

<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Derocking</th>
<th>Mechanization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases yield</td>
<td>Provides a good growing medium</td>
<td>Enables savings in labour and cost</td>
</tr>
<tr>
<td>Ensures sustainable production</td>
<td>Facilitates irrigation</td>
<td>Provides rapidity/timeliness of cultural operations</td>
</tr>
<tr>
<td>Allows fertilizer application in water</td>
<td>Facilitates mechanization</td>
<td>Operates during day and night</td>
</tr>
<tr>
<td></td>
<td>Provides additional area for cultivation</td>
<td>Provides prompt intervention for cane harvest after a fire event</td>
</tr>
</tbody>
</table>

The key benefits of irrigation, derocking and mechanization are summarized in **Table 4**. The three field measures cannot be carried out in isolation without due considerations for satisfying the requirements of one another.

**CONCLUSION**

Given the critical situation and challenges of the sugar cane industry, it has been necessary to investigate the current status and practices of irrigation, derocking and mechanization in the context of strategic planning. The findings of studies on the three measures and the maps produced are useful to stakeholders, planners and decision makers in their efforts to increase the competitiveness of the sugar cane industry. To accelerate the application of these measures, there are needs for increased support and incentives from governmental and other related bodies. On the other hand, certain issues related to land conversion, interrow cropping, small plots and individual as opposed to collective investments by planters will have to be properly addressed as these issues may have a negative impact on the programmes.

It is expected that the increase in sugar production from additional irrigated areas and areas freed from under rock piles will sufficiently compensate the reduction in total sugar production that is likely to result from the conversion of more cane land during the next three to five years.

**ACKNOWLEDGEMENT**

The suggestions and comments from the Director of the Mauritius Sugar Industry Research Institute are gratefully acknowledged.

**REFERENCES**


ENHANCING SUGAR CANE PRODUCTION IN THE MARGINAL SOILS THROUGH THE ADOPTION OF APPROPRIATE VARIETIES

K Pillay Samoo, C Travailleur, KP Pillay and J Gauthier

Mauritius Sugar Industry Research Institute

ABSTRACT

The sugar cane breeding programme of the Mauritius Sugar Industry Research Institute is primarily geared towards the development of varieties for the major soil groups in different agro-climatic environments, which represent about 83% of the area under sugar cane cultivation in Mauritius. However, for the marginal soils, no specific breeding programme exists. Since 1996, variety trials have been initiated in different regions of the island where the area of marginal land is significant. The objective of this study was to evaluate the performance of a number of promising and newly released varieties bred for the major soil group in these soils. In most of the trials, a few tested varieties were systematically more productive than the standard ones. The results of the study have contributed to fine-tune variety recommendations for the marginal soils, that have enhanced sugar production through the adoption of better performing varieties.

Keywords: cane breeding, promising varieties, sugar production

INTRODUCTION

The Mauritius Sugar Industry Research Institute (MSIRI) is committed to enhance the competitiveness of the sugar cane industry within the changing global context. The development of superior commercial varieties is a major thrust of the research strategy at the MSIRI. The breeding and selection programme of the Institute is primarily focused towards the production of new varieties adapted to the different agro-climatic environments of the major soil groups in Mauritius. However, no specific programmes involving variety trials exist for the marginal soils. These undifferentiated soil groups have physical and climatic constraints, which strongly limits the crop productivity. The Marginal soils represent about 17% of the total area under sugar cane cultivation (Jhoty et al. 2002) and consist of Mountain Slope Complex soils (43%) and Lithosols (38%). The Mountain Slope Complex soils (MSC) are generally found on moderate to steep slopes, with varying soil depth and degree of rockiness. They are mostly found in the North near La Nicolère, in the region of Baie du Cap in the South and extend from Deux Frères, through Grand Sable to Ferney in the south east region. The Lithosols (T) are skeletal soils, developed on hummocky bed-rocks (Parish & Feillafé 1965). They cover an important area extending from Poste de Flacq, through Belle Mare to Trou d'Eau Douce in the dry Eastern region. Full mechanization and derocking to improve productivity in these soils are not feasible because of severe physical constraints and high investment cost involved for land planning and layout. Irrigation is also limited due to the unavailability of water. Hence, the selection of more productive varieties to replace poorly performing ones is becoming increasingly important to sustain sugar cane productivity in these regions. In this perspective, variety trials were initiated in 1996, to evaluate the performance of a series of newly released and promising varieties in comparison with the existing ones. Yield data were used to assess and select the most performing varieties for these specific niches. The ultimate goal of this study was to establish fine-tune variety recommendations for the marginal soils in view of enhancing the sugar production.
MATERIALS AND METHODS

Four variety trials were established, during 1996 to 1998, in four different environments using the randomised complete block design with three replicates. Two trials were planted in the Lithosols at Trou d’Eau Douce and Belle Mare, two sections of a Sugar Estate and the other two in the Mountain Slope Complex soils at Grand Sable and Baie du Cap. The characteristics of the marginal soils in each region are given in Table 1. The most important varieties grown commercially as well as newly released and promising varieties were included in the trials. The experimental plots were planted at the same time as the commercial fields, and harvested at approximately 12 months of age over a period of four years. The plot size was four rows of 10 m each, with row spacing of 1 m 46 or 1 m 50. All the trials were rainfed except that of Belle Mare which received overhead irrigation on an occasional basis, depending on water availability. Planting, fertilization and harvesting were monitored by officers of the Extension Department of the MSIRI. All the other field operations, similar to practices in commercial fields, were effected by the planters. Regular field visits were carried out to ensure proper weed management, observe incidence of pests and diseases, and assess the agronomic characteristics of the tested varieties.

<table>
<thead>
<tr>
<th>Region</th>
<th>Grand Sable</th>
<th>Trou D’Eau Douce</th>
<th>Belle Mare</th>
<th>Baie du Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil type</td>
<td>Mountain Slope Complex</td>
<td>Lithosols *</td>
<td>Mountain Slope Complex</td>
<td></td>
</tr>
<tr>
<td>Soil family</td>
<td>S2</td>
<td>T3</td>
<td>S1</td>
<td></td>
</tr>
<tr>
<td>Degree of rockiness</td>
<td>Only weathered rock, no rock in the profile</td>
<td>Very rocky</td>
<td>Unweathered rock in the profile</td>
<td></td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep &gt; 30 cm</td>
<td>Shallow 10-25 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topography</td>
<td>Moderate to steep slope</td>
<td>Almost flat to hummocky</td>
<td>Moderate to steep slope</td>
<td></td>
</tr>
<tr>
<td>Mean annual rainfall</td>
<td>1 800 - 2 000</td>
<td>1 300 - 1 500</td>
<td>1 250 - 1 600</td>
<td></td>
</tr>
</tbody>
</table>

* Refer Soils Map of Mauritius by Parish and Feillafé 1965

At harvest, the cane yield was determined by weighing the two middle rows of each plot, and Industrial Recoverable Sucrose % Cane (IRSC), was calculated from a sample of 10-cane stalks using the method devised by De Saint Antoine (1968). These data were processed and analysed statistically to determine the sugar yield per hectare (TSH) for each variety. The cumulative results of the plant cane and three subsequent ratoons (P123) were used for comparison and selection of varieties to establish recommendations for the marginal soils. Data collected on the estate at Grand Sable (40 ha) and on the two sections of the Sugar Estate (2597 ha) enabled an assessment of the adoption rate and performance of new varieties on a commercial scale. Results of the trials were discussed with other planters and regional visits organized to allow them to evaluate the varieties in their conditions for future adoption. The details of the trials are given in Table 2.

RESULTS AND DISCUSSION

Harvest results

At Grand Sable, var M 1176 / 77 significantly outyielded the standard vars R 570 and M 555 / 60 by 22% (Table 3). Var R 573 was more productive than the average standards, but the yield was inferior to var R 570 and was therefore recommended for harvest early in the season when its sugar content is higher than that of var R 570 (Domaingue and Autrey 1998). Although the performance of R 579 was...
Enhancing sugar cane production in the marginal soils through the adoption of appropriate varieties. *K Pillay Samoo* et al.

better than that of the two standards, the variety was not multiplied due to its susceptibility to gumming disease.

**Table 2** Details of trials at the different sites

<table>
<thead>
<tr>
<th>Geographical sector</th>
<th>East</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Trou d’Eau Douce</td>
<td>Belle Mare</td>
</tr>
<tr>
<td>Area of section / estate ( ha )</td>
<td>641.5</td>
<td>713.8</td>
</tr>
<tr>
<td>% of marginal soil</td>
<td>71.3 % T3</td>
<td>100 % T3</td>
</tr>
<tr>
<td>Annual rainfall ( mm )</td>
<td>1 300</td>
<td>1 300</td>
</tr>
<tr>
<td>Date planted</td>
<td>21 Mar 97</td>
<td>1 Apr 1998</td>
</tr>
<tr>
<td>Last harvest date</td>
<td>28 Aug 01</td>
<td>30 Jul 02</td>
</tr>
<tr>
<td>Row spacing ( m )</td>
<td>1.46</td>
<td>1.46</td>
</tr>
</tbody>
</table>

**Table 3** Cumulative results of the trial at Grand Sable (mean of plant cane, 1st, 2nd and 3rd ratoons)

<table>
<thead>
<tr>
<th>Variety</th>
<th>TCH</th>
<th>IRSC (%)</th>
<th>TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 555 / 60</td>
<td>79.53</td>
<td>10.75</td>
<td>8.55</td>
</tr>
<tr>
<td>R 570</td>
<td>89.34</td>
<td>11.10</td>
<td>9.92</td>
</tr>
<tr>
<td>Average</td>
<td>84.43</td>
<td>10.93</td>
<td>9.23</td>
</tr>
<tr>
<td>M 1176 / 77</td>
<td>100.20</td>
<td>11.24</td>
<td>11.26</td>
</tr>
<tr>
<td>M 261 / 78</td>
<td>81.98</td>
<td>11.08</td>
<td>9.09</td>
</tr>
<tr>
<td>M 1551 / 89</td>
<td>82.03</td>
<td>11.09</td>
<td>9.09</td>
</tr>
<tr>
<td>R 573</td>
<td>88.00</td>
<td>11.01</td>
<td>9.69</td>
</tr>
<tr>
<td>R 575</td>
<td>74.70</td>
<td>11.24</td>
<td>8.39</td>
</tr>
<tr>
<td>R 579</td>
<td>97.75</td>
<td>10.84</td>
<td>10.59</td>
</tr>
<tr>
<td>R 70353</td>
<td>87.50</td>
<td>11.04</td>
<td>9.66</td>
</tr>
<tr>
<td>Average</td>
<td>87.45</td>
<td>11.08</td>
<td>9.68</td>
</tr>
<tr>
<td>Trial average</td>
<td>86.78</td>
<td>11.04</td>
<td>9.58</td>
</tr>
<tr>
<td>s.e ±</td>
<td>1.3994</td>
<td>0.2652</td>
<td>0.1694</td>
</tr>
</tbody>
</table>

IRSC: Industrial Recoverable Sugar % Cane (De Saint Antoine, 1968)

The performances of most varieties under test at Trou d’Eau Douce were better than the average standards (**Table 4**). Var R 573 was superior by 17% to all other varieties in terms of sugar yield whereas M 1176 / 77 was the best performing one as regards cane yield. The two varieties were therefore recommended for planting on commercial scale. However, growers were advised to harvest var M 1176 / 77 on the second half of the season on account to its average to low sugar content. (Domaingue et al. 1996). Since the variety flowers profusely, it was also recommended to monitor late harvest in order to reduce losses due to pithiness (MSIRI 1998).
Table 4 Cumulative results of trial at Trou d’Eau Douce (mean of plant cane, 1st, 2nd and 3rd ratoons)

<table>
<thead>
<tr>
<th>Variety</th>
<th>TCH</th>
<th>IRSC (%)</th>
<th>TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 555 / 60</td>
<td>52.56</td>
<td>10.75</td>
<td>5.65</td>
</tr>
<tr>
<td>R 570</td>
<td>53.67</td>
<td>11.37</td>
<td>6.10</td>
</tr>
<tr>
<td>Average</td>
<td>53.11</td>
<td>11.06</td>
<td>5.88</td>
</tr>
<tr>
<td>M 1176 / 77</td>
<td>63.70</td>
<td>10.30</td>
<td>6.56</td>
</tr>
<tr>
<td>M 261 / 78</td>
<td>59.67</td>
<td>11.25</td>
<td>6.71</td>
</tr>
<tr>
<td>M 1551 / 80</td>
<td>57.78</td>
<td>10.57</td>
<td>6.10</td>
</tr>
<tr>
<td>M 96 / 82</td>
<td>62.95</td>
<td>10.16</td>
<td>6.40</td>
</tr>
<tr>
<td>M 1246 / 84</td>
<td>59.64</td>
<td>11.08</td>
<td>6.61</td>
</tr>
<tr>
<td>R 573</td>
<td>61.11</td>
<td>11.28</td>
<td>6.90</td>
</tr>
<tr>
<td>Varieties under test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R 575</td>
<td>49.45</td>
<td>11.40</td>
<td>5.63</td>
</tr>
<tr>
<td>R 579</td>
<td>54.50</td>
<td>11.75</td>
<td>6.40</td>
</tr>
<tr>
<td>Average</td>
<td>58.60</td>
<td>10.94</td>
<td>6.41</td>
</tr>
<tr>
<td>Trial average</td>
<td>57.50</td>
<td>10.97</td>
<td>6.31</td>
</tr>
</tbody>
</table>

Table 5 Cumulative results of trial at Belle Mare (mean of plant cane, 1st, 2nd and 3rd ratoons)

<table>
<thead>
<tr>
<th>Variety</th>
<th>TCH</th>
<th>IRSC (%)</th>
<th>TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 695 / 69</td>
<td>76.61</td>
<td>11.56</td>
<td>8.85</td>
</tr>
<tr>
<td>M 1557 / 70</td>
<td>88.20</td>
<td>11.35</td>
<td>10.01</td>
</tr>
<tr>
<td>R 570</td>
<td>84.42</td>
<td>11.38</td>
<td>9.61</td>
</tr>
<tr>
<td>Average</td>
<td>83.08</td>
<td>11.43</td>
<td>9.49</td>
</tr>
<tr>
<td>M 1176 / 77</td>
<td>92.64</td>
<td>12.08</td>
<td>11.19</td>
</tr>
<tr>
<td>M 1551 / 80</td>
<td>97.61</td>
<td>11.69</td>
<td>11.41</td>
</tr>
<tr>
<td>M 96 / 82</td>
<td>91.81</td>
<td>11.18</td>
<td>10.26</td>
</tr>
<tr>
<td>M 1246 / 84</td>
<td>94.17</td>
<td>11.09</td>
<td>10.44</td>
</tr>
<tr>
<td>R 573</td>
<td>89.61</td>
<td>11.68</td>
<td>10.46</td>
</tr>
<tr>
<td>R 575</td>
<td>91.06</td>
<td>12.21</td>
<td>11.12</td>
</tr>
<tr>
<td>Average</td>
<td>92.82</td>
<td>11.66</td>
<td>10.81</td>
</tr>
<tr>
<td>Trial average</td>
<td>89.57</td>
<td>11.58</td>
<td>10.37</td>
</tr>
</tbody>
</table>

At Belle Mare, vars M 1176 / 77, R 575 and M 1551 / 80 harvested early in the season were superior to the average standards R 570, M 1557 / 70 and M 695 / 69 by at least 17% (Table 5) and were therefore recommended for further multiplication. It was observed that the IRSC % of M 1176 / 77 which is a variety for mid to late harvest was unexpectedly high at early harvest. This could be attributed to the irrigation regime in this dry and rocky environment, since at Trou D’Eau Douce under the same conditions but without irrigation its IRSC % was lower than most of the varieties in the trial early in the season. This area requires further investigation.

At early harvest, in the trial at Baie du Cap, vars M 1176 / 77, M 1246 / 84 and R 573 were more productive than the average standards R 570 and M 555 / 60 by around 21% (Table 6). These varieties were therefore recommended for planting in commercial fields.
Table 6 Cumulative results of trial at Baie du Cap
(mean of plant cane, 1st, 2nd and 3rd ratoons)

<table>
<thead>
<tr>
<th>Variety</th>
<th>TCH</th>
<th>IRSC(%)</th>
<th>TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Varieties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 555 / 60</td>
<td>62.78</td>
<td>9.38</td>
<td>5.89</td>
</tr>
<tr>
<td>R 570</td>
<td>61.86</td>
<td>9.55</td>
<td>5.91</td>
</tr>
<tr>
<td>Standard average</td>
<td>62.32</td>
<td>9.47</td>
<td>5.90</td>
</tr>
<tr>
<td>Varieties under test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 1176 / 77</td>
<td>70.95</td>
<td>10.10</td>
<td>7.16</td>
</tr>
<tr>
<td>M 261 / 78</td>
<td>62.11</td>
<td>10.03</td>
<td>6.23</td>
</tr>
<tr>
<td>M 1551 / 80</td>
<td>57.86</td>
<td>10.03</td>
<td>5.81</td>
</tr>
<tr>
<td>M 1246 / 84</td>
<td>67.52</td>
<td>10.59</td>
<td>7.15</td>
</tr>
<tr>
<td>R 573</td>
<td>66.06</td>
<td>11.15</td>
<td>7.36</td>
</tr>
<tr>
<td>R 575</td>
<td>58.28</td>
<td>11.05</td>
<td>6.44</td>
</tr>
<tr>
<td>Average</td>
<td>63.80</td>
<td>10.49</td>
<td>6.69</td>
</tr>
<tr>
<td>s.e ±</td>
<td>1.6874</td>
<td>0.1821</td>
<td>0.1816</td>
</tr>
</tbody>
</table>

Although the mean annual rainfall and the soil type were the same at Belle Mare and Trou d’Eau Douce, yields were generally higher at Belle-Mare (Tables 1 & 2) due to the provision of irrigation. The trials at Grand Sable and Baie du Cap were both in the MSC soils, however yields were generally higher at Grand Sable owing to the higher mean annual rainfall and deeper soils (Tables 1 & 2).

Adoption and performance of varieties

At Grand Sable, the predominant variety M 555 / 60 which covered 23.9 ha (60%) of the area under cane in 1997 (Figure 1), occupied only 14.6 ha (25%) in 2002. Vars M 695 / 69 and M 1557 / 70 were phased out by end 2002. On the basis of preliminary results from the trial, var M 1176 / 77 was planted commercially in 1999 and subsequently var R 573 in 2000. In 2002, these two varieties occupied 11.4 ha (28%) of the estate. Cane yields in commercial fields highlighted the superiority of var M 1176 / 77 over other varieties (Figure 2). The performance of var R 573 was comparable to that of var R 570. However, a slight increase in yield was observed with var R 573 in the older ratoons and the reverse for var R 570.

At Argy and Belle Mare, emphasis was on the phasing out of vars M 555 / 60, M 447 / 67 and M 1156 / 66 (Figure 3). The area under var R 570 was at its peak in 1999, when it occupied about 700 ha (60%), but in 2002 that area dropped to 519 ha (43.3%). From 1998 to 2002, the area under M 695 / 69 was almost halved. A significant increase in the area under var M 1176 / 77 was observed as from 1997 onwards and in 2002 the variety occupied 24% of the cultivated area. Early maturing vars M 1551 / 80, R 573 and R 575 were introduced on the estate in 2000, but only R 573 and R 575 were further multiplied owing to their good performance on commercial scale. Although M 1551 / 80 was the most productive variety in the trial at Belle Mare, it was not propagated since the grower observed stool death in ratoons and also because of its susceptibility to breakage during cyclones. The performance of the most productive varieties planted on a commercial scale at Belle Mare and Argy sections compared to that of var R 570, the most widely planted commercial variety in 2002 is represented in Figure 4. Vars M 1176 / 77, R 575 and R 573 were significantly more productive than R 570.

The adoption of better performing varieties by a planter cultivating about 110 ha of Lithosols (T3) in the ex-Constance factory area is illustrated in Figure 5. In 1997, the estate was primarily under var R 570 (83%), and to a lesser extent (9%) under var M 13 / 56 which was phased out completely in 1998. In 1999, R 570 was the only cultivated variety on the estate. As from 2000 onwards, the area under R 570 decreased progressively and by 2002, 33% of the variety has been replaced by vars R 573 and M 1176 / 77.
Enhancing sugar cane production in the marginal soils through the adoption of appropriate varieties. K Pillay Samoo et al.

**Figure 1** Variety distribution on the Estate at Grand Sable (1997-2002)

**Figure 2** Evolution of cane yield in commercial fields on the Estate at Grand Sable (average of 1997-2002 crops, excluding 1999)
Enhancing sugar cane production in the marginal soils through the adoption of appropriate varieties. *K Pillay Samoo* et al.

**Figure 3** Evolution of area cultivated under different varieties at Argy and Belle Mare

![Figure 3](image)

**Figure 4** Performance of different varieties at Argy and Belle Mare in 2002

![Figure 4](image)
Figure 5  Evolution of area cultivated under different varieties on the Estate in ex-Constance factory area

CONCLUSION

This study showed the good performance of var M 1176 /77 which systematically outclassed the standards at all sites. The results also revealed the high potential of vars R 573 and R 575 at early harvest under rainfed and irrigated conditions respectively. The good performance of these three varieties on commercial scale confirmed their adaptation to the marginal soils.

Information resulting from research and development remains of academic value unless effectively conveyed to potential users. Emphasis is therefore placed on dissemination of the results to other growers to enhance their sugar production. This study highlights the importance of on-farm experimentation to accelerate the adoption of research findings. Since total mechanization which is vital for the survival of the Mauritian industry is unlikely to occur in these regions, increase in yield through the adoption of better performing varieties is probably the best way to ensure economic viability and the survival of sugar cane growers operating in these marginal areas.

ACKNOWLEDGEMENT

We thank Dr LJC Autrey, Director of MSIRI, for his usual support and valuable comments and suggestions on this manuscript.

REFERENCES


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AIR-INCLUSION NOZZLES FOR IMPROVED HERBICIDE APPLICATION IN SUGAR CANE

S Seeruttun, C Barbe and A Gaungoo
Mauritius Sugar Industry Research Institute

ABSTRACT

In Mauritius, flood jet and double hollow cone nozzles are used on knapsack sprayers for applying herbicides in sugar cane whereas standard flat fan nozzles are most common on boom sprayers. The spray distribution from all these nozzles include fine droplets that may be easily carried by wind and cause damage to susceptible crops grown in the neighbourhood. Air-inclusion nozzles (flat fan type), designed to produce coarser droplets and reduce spray drifts, have been evaluated for herbicide application in sugar cane; the new nozzles were tested more particularly for their herbicidal efficacy in post-emergence of weeds and sugar cane. Results show that post-emergence weed control obtained by the Air-Bubble Jet nozzles is comparable to the hollow cone nozzles (on knapsack sprayers) and flat fan nozzles (boom sprayers). Air Inclusion (wide angle) nozzles tested on knapsack sprayers were found to be superior to the flood jet nozzles and comparable to double cone jet nozzles. With two passes per cane interrow, an Air Inclusion (wide angle) nozzle mounted on a knapsack sprayer enables significant reduction of spray volume usually required with the double cone jet nozzles.

Keywords: flat fan nozzles, double hollow cone nozzles, flood jet nozzles, drift, spray volume

INTRODUCTION

Weed control in sugar cane is achieved mainly by use of herbicides and some 425 tonnes of active ingredients are applied on approximately 77 000 ha under sugar cane in Mauritius. Two or three herbicide treatments are required per crop season; the first treatment normally consists of pre-emergence herbicides and the subsequent ones of tank-mixtures containing pre- and post-emergence herbicides. Knapsack sprayers have extensively been used for applying herbicides in sugar cane, mechanical spraying has increased in the recent years but area treated does not exceed 30%. The two most common nozzles used on knapsack sprayers for herbicide application are hollow cone and flood jet nozzles. In post-emergence of weeds and cane, two hollow cone nozzles mounted at the end of the spray lance to have a larger swath are preferred to flood jet nozzles as they provide better coverage and penetration within the canopy. However, the double cone nozzles produce relatively fine droplets which are prone to drifts and use relatively higher spray volumes. The spray volumes with double cone nozzles vary between 475 to 640 L ha\(^{-1}\). For mechanical spraying of herbicides, standard flat fan nozzles are used on the booms with spray volume varying between 225 and 250 L ha\(^{-1}\).

In Mauritius, vegetables grown in the vicinity of sugar cane fields pose serious constraints to sugar cane producers as the two mostly used post-emergence herbicides are hormone type in nature; any drifts would cause severe distortions and damage to the susceptible crops grown in neighbouring fields. An alternative herbicide treatment has now been proposed (Barbe et al. 2002) but it does not preclude reduction of herbicide drifts.

In general, smaller droplets are considered biologically more effective than large droplets for herbicide application (Knoche 1994) whereas the larger droplets are less easily carried by drifts. Air-inclusion nozzles have been developed to minimize air-borne drifts from agricultural sprays by using an integral venturi to draw air into the pumped liquid stream before being sprayed through a conventional fan jet. Air Bubble Jet (ABJ) developed by Billericay Farm Services utilises the inclusion of air into the liquid stream to break the normal relationship between coverage and drift by including air bubbles in the larger drops (Cecil 1997). ABJ nozzles were the first air-inclusion nozzles available in Mauritius; they have been tested on field sprayers (designed for use at 0.5 m spacings on the boom and at a spray height of 0.5 m). To benefit from drift reduction, the ABJ nozzles have also been fitted on knapsack sprayers.
Air-inclusion nozzles for improved herbicide application in sugar cane. S Seeruttun, C Barbe and A Gaungoo

sprayers; two nozzles mounted at the tip of the spray lance to increase the swath. Wide angle air-injet nozzles (AI110025VS from Teejet), i.e. flat fan nozzles with air-inclusion and with a spray angle of 100° to 120°, have also been tested on knapsack sprayers as the larger swath with a single nozzle can cover a cane interrow of 1.60 m within two passes.

This paper reports on trials established since 1998 to evaluate the use of air-inclusion (ABJ and wide angle air-injet) nozzles for herbicide spraying in sugar cane. The main objective of this study was to evaluate the ‘herbicidal’ efficacy of these new nozzles; all trials have been conducted in post-emergence of cane and weeds to better appreciate their potential. Practical constraints and other advantages of using air-inclusion nozzles on knapsack sprayers are also discussed.

MATERIALS AND METHODS

Five field trials have been conducted, since 1998, at Olivia, Beau Vallon, Union Park, Belle Mare and Belle Rive. As these nozzles have been primarily developed for use on boom or field sprayers, the first two trials consisted of comparing the efficacy of ABJ nozzles to standard nozzles for mechanical spraying of herbicides in sugar cane. The other trials have studied the possibility of using ABJ and wide angle air-injet nozzles on knapsack sprayers. The different treatments in each trial are given below.

Trial I

The first trial was laid down at Olivia, H soil group (Parish and Feillafé 1965) where two air-injet nozzles were compared to a low-drift nozzle and a standard flat fan one for mechanical spraying of herbicides in early post-emergence of weeds and ratoon cane (var M 695/69). The field was harvested on 26 September 1998 and sprayed on 22 October 1998. The two Air-Bubble Jet nozzles (from Billericay Farm Services LTD, Downham, Billericay, Essex, UK) consisted of the yellow (0.2) and blue (0.3) colour-coded ones. The driving speed of the tractor was 4.8 km hr⁻¹ and spraying pressure fixed at 250 kPa. The herbicide treatment consisted of a tank-mix of metolachlor + atrazine + 2,4-D amine salt @ 2.0 + 2.0 + 2.0 kg a.i/a.e. ha⁻¹; an untreated control was also included. The spray volumes used were 150, 225, 275 L ha⁻¹ for the yellow air-injet, blue air-injet, low-drift and 225 L ha⁻¹ for the standard flat fan nozzles. Each plot consisted of five cane rows spaced at 1.6 m and each treatment was replicated three times in a completely randomized block design. Observations were made two and six weeks after spraying and a weed population surveyed on 24 December 1998 (9 weeks after spraying) using the frequency abundance method (Rochecouste 1968).

Trial II

The blue colour-coded ABJ nozzles were further compared to standard flat fan nozzles for mechanical spraying of herbicides in post-emergence of weeds and sugar cane (var M 695/69) at Beau Vallon (H soil group) in 1998. The nozzles were mounted on a 7 m boom operating at 250 kPa and with driving speed of 4.5 km hr⁻¹. A treatment consisting of manual spraying, using Knapsack sprayers with double hollow cone nozzles delivering 640 L ha⁻¹ of spray mixture at a walking speed of 0.75 m/s and with two passes per interrow, was also included.

The herbicide treatment consisted of a tank-mix of metolachlor + atrazine + 2,4-D amine salt @ 2.0 + 2.0 + 2.0 kg a.i/a.e. ha⁻¹ and was applied on 5 October 1998. Plot size consisted of four cane rows over the length of the field and each treatment was replicated three times. Weed surveys were carried out before and five weeks after spraying to assess efficacy of the various treatments.

Trial III

The use of air-inclusion nozzles on hand-operated knapsack sprayers was evaluated in this trial at Union Park (B soil group) in 2000. Two ABJ nozzles were mounted on the spray boom to increase their individual swaths of 0.4 m to about 0.8 – 0.9 m at a nozzle height of 0.3-0.35 m from ground. With the two nozzles mounted at the end of the spray lance, a cane interrow, 1.6 m wide, was covered by two passes per interrow. Three colour-coded air-injet nozzles were tested; a green (0.15), yellow
Air-inclusion nozzles for improved herbicide application in sugar cane. S Seeruttun, C Barbe and A Gaungoo


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(0.2) and blue (0.3) nozzle delivering approximately 350, 475 and 640 L ha\(^{-1}\) of spray mixture with two nozzles were compared to the double hollow cone nozzles delivering 475 L ha\(^{-1}\) at a walking speed of 0.75 m s\(^{-1}\). Spraying was carried out in post-emergence of weeds and sugar cane, the herbicide treatment consisting of a tank-mix with hexazinone + diuron + 2,4-D amine salt @ 0.6 + 2.0 + 2.0 kg a.i./a.e. ha\(^{-1}\). Each plot consisted of four cane rows of 7 m with an interrow spacing of 1.6 m and all treatments were replicated three times.

A survey was carried out before spraying using the frequency abundance method on the day of spraying (16 October 2000) and the % kill obtained with each treatment was calculated after a second survey made on 6 November 2000 (3 weeks after spraying).

**Trial IV**

Two Air Inclusion - wide angle (AI-WA) nozzles were compared to standard double cone and flood jet nozzles at Belle-Mare (T soil group) in 2002. A swath of approximately 0.9 m was obtained by each wide angle nozzle at a spraying height of 30 to 35 cm; this implied that only one nozzle was sufficient to cover a cane interrow with two passes. The AI-WA nozzles, one blue colour-coded (AI11003-VS) and a pale blue (AI110025-VS) from Spraying Systems Teejet were calibrated to deliver 300 and 250 L ha\(^{-1}\) of spray mixture. The double cone nozzles delivered 475 L ha\(^{-1}\) with two passes per interrow whereas the flood jet nozzle was calibrated at 300 L ha\(^{-1}\) with only one pass per interrow.

Spraying was made in post-emergence of weeds and cane on 14 August 2002. A weed survey was made prior to spraying and the herbicide treatment consisted of a tank-mix of tebuthiuron + atrazine + 2,4-D amine salt @ 1.3 + 2.0 + 2.0 kg a.i./a.e. ha\(^{-1}\). The four nozzle treatments plus an untreated control were replicated three times with a plot size of 144 m\(^2\) (3 cane interrows x 30 m). A first assessment was made four weeks after spraying and a final survey carried on 18 October 2002.

**Trial V**

A second trial to evaluate the efficacy of the Air Inclusion - wide angle (AI-WA) nozzles (mounted on a knapsack sprayer) was established in January 2003 at Belle Rive (F soil group). The same two AI-WA nozzles tested in Trial IV were compared to double-cone nozzles for application of herbicides in post-emergence of weeds and ratoon cane (var M 3035/66). The blue AI-WA, pale-blue AI-WA and double cone nozzles were calibrated to deliver 350, 275 and 400 L ha\(^{-1}\) of spray mixture. A standard tank-mix of tebuthiuron + atrazine + 2,4-D amine salts @ 1.3 + 2.0 + 2.0 kg a.i./a.e. ha\(^{-1}\) was applied and an untreated control was also included. The plot size consisted of four cane rows of 6.5 m each and each treatment replicated four times. Data collected comprised a weed assessment and the % weed cover on day of spraying and five weeks after spraying.

**RESULTS**

**Trial I**

Two weeks after spraying, the few weed seedlings present in all treated plots on day of spraying had died. A few weeds (Cyperus rotundus and Oxalis latifolia – two species not controlled by the pre-emergence products in the tank-mix) were observed in all treated plots six weeks after spraying while the untreated plots were infested by Ageratum conyzoides, Ananarthus viridis, Bothriospermum tenellum, Cyperus rotundus, Digitaria horizontalis, Euphobia hirta, Euphorbia hypericifolia, Oxalis corniculata, Oxalis latifolia, Phyllanthus sp., and Solanum nigrum. The final survey showed the level of pre-emergence control obtained by the blue colour-coded ABJ nozzles was comparable to those obtained by the standard nozzles; the yellow ABJ nozzles seemed to be slightly inferior (Table 1).

Table 1  Efficacy of Air-Bubble Jet (ABJ) nozzles for mechanical spraying of pre/post-emergence herbicides in sugar cane

<table>
<thead>
<tr>
<th>Nozzles</th>
<th>Spray volume L ha⁻¹</th>
<th>Weed abundance (% of untreated control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard flat fan</td>
<td>225</td>
<td>32</td>
</tr>
<tr>
<td>Low-drift</td>
<td>275</td>
<td>34</td>
</tr>
<tr>
<td>ABJ (Yellow)</td>
<td>150</td>
<td>40</td>
</tr>
<tr>
<td>ABJ (Blue)</td>
<td>225</td>
<td>33</td>
</tr>
</tbody>
</table>

**Trial II**

The main weed species present at Beau Vallon before spraying were *Ageratum conyzoides*, *Bidens pilosa*, *Brachiaria eruciformis*, *Cyperus rotundus*, *Digitaria horizontalis*, *Oxalis corniculata*, *Panicum subalbidum*, *Phyllanthus sp.*, *Solanum nigrum* and *Youngia japonica*. The herbicide treatment applied provided a good control of all broad-leaved weeds and some of the grasses. The second survey showed that the level of control obtained by the ABJ nozzles was comparable to the standard flat fan nozzles mounted on the same boom and was superior to the double cone nozzles on the knapsack sprayer (Table 2).

Table 2  Efficacy of Air-Bubble Jet nozzles for mechanical spraying of post-emergence herbicides in sugar cane

<table>
<thead>
<tr>
<th>Nozzles</th>
<th>Spray volume L ha⁻¹</th>
<th>% weed kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard flat fan</td>
<td>225</td>
<td>64.3</td>
</tr>
<tr>
<td>Double hollow cone (Knapsack)</td>
<td>475</td>
<td>59.5</td>
</tr>
<tr>
<td>ABJ (Blue)</td>
<td>225</td>
<td>68.8</td>
</tr>
</tbody>
</table>

**Trial III**

A very good control of weeds, irrespective of nozzle types and delivery, was obtained in all treated plots; the main weeds recorded in the untreated control were *Solanum nigrum*, *Youngia japonica*, *Sonchus asper*, *Gnaphalium polycaulon*, *Kyllinga bulbos*, *Lobelia clifortiana* and *Drymaria cordata*. A very good level of control was obtained with the herbicide treatment and the three ABJ nozzles were as effective as the double cone nozzles (Table 3).

Table 3  Efficacy of Air-Bubble Jet (ABJ) nozzles for knapsack spraying of post-emergence herbicides in sugar cane

<table>
<thead>
<tr>
<th>Nozzles</th>
<th>Spray volume L ha⁻¹</th>
<th>% weed kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double hollow cone</td>
<td>400</td>
<td>98.7</td>
</tr>
<tr>
<td>ABJ - green</td>
<td>375</td>
<td>96.7</td>
</tr>
<tr>
<td>ABJ - yellow</td>
<td>475</td>
<td>98.1</td>
</tr>
<tr>
<td>ABJ - blue</td>
<td>640</td>
<td>96.9</td>
</tr>
</tbody>
</table>
Trial IV

A weed survey made prior to spraying revealed that the main weeds present in the field were *Ageratum conyzoides*, *Apium leptophyllum*, *Chloris barbata*, *Cyperus rotundus*, *Digitaria horizontalis*, *Euphorbia hirta*, *Oxalis corniculata*, *Paederia foetida*, *Phyllathus sp.* and *Sonchus asper*. Four weeks after spraying all broad-leaved weeds were eradicated completely and the treatment was less effective against *Digitaria horizontalis* particularly in the cane rows. The final survey revealed that the efficacy obtained with the double hollow cone nozzles was superior to the flood jet and AI-WA blue (AI11003VS) nozzles and comparable to the AI-WA pale blue (AI110025VS) (Table 4).

<table>
<thead>
<tr>
<th>Nozzles</th>
<th>Spray volume L ha⁻¹</th>
<th>% Weed kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double hollow cone</td>
<td>475</td>
<td>73.7</td>
</tr>
<tr>
<td>Floodjet</td>
<td>300</td>
<td>64.3</td>
</tr>
<tr>
<td>AI-WA (pale blue – AI110025VS)</td>
<td>250</td>
<td>70.2</td>
</tr>
<tr>
<td>AI-WA (blue – AI11003VS)</td>
<td>300</td>
<td>61.7</td>
</tr>
</tbody>
</table>

Trial V

The main weeds present before spraying at Belle Rive were *Ageratum conyzoides*, *Bidens pilosa*, *Digitaria horizontalis*, *Drymaria cordata*, *Erigeron canadensis*, *Paspalum paniculatum*, *Paspalum urvillei* and *Setaria pallide-fusca*. The herbicide treatment was very effective against the broad-leaved weeds and weeds left thereafter were mainly *D. horizontalis* and *P. urvillei*. The final weed survey made five weeks after spraying showed that the two air inclusion nozzles were slightly superior to the double cone nozzles; no difference was observed between the air inclusion nozzles (Table 5).

<table>
<thead>
<tr>
<th>Nozzles</th>
<th>Spray volume L ha⁻¹</th>
<th>% Weed kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double hollow cone</td>
<td>475</td>
<td>59.4</td>
</tr>
<tr>
<td>AI-WA (pale blue – AI110025VS)</td>
<td>275</td>
<td>65.3</td>
</tr>
<tr>
<td>AI-WA (blue – AI11003VS)</td>
<td>350</td>
<td>66.2</td>
</tr>
</tbody>
</table>

DISCUSSION

For mechanical spraying, the ABJ nozzles have been comparable to the standard flat fan nozzles; the weakness of the yellow colour-coded (ABJ – 0.2) was most probably due to the size of the droplets. Very small droplets attain their terminal velocity earlier (Bode 1987) and thus have less energy for penetration within the crop/weed canopy. The slight difference in favour of mechanical spraying to manual spraying observed in Trial II is explained by the more homogeneous spray pattern from the boom compared to manual application where waving of the spray lance is required to increase swath. This waving movement, irrespective of nozzles used, often results in uneven spray patterns.
Air-inclusion nozzles for improved herbicide application in sugar cane. S Seeruttun, C Barbe and A Gaungoo

Trial III has shown that two ABI nozzles may be used on a knapsack effectively but this is achieved by a relatively high spray volume. For knapsacks, the use of the AI-WA nozzles seems more interesting as one nozzle is sufficient to provide a swath covering more than half of the cane interrow and requires significantly lower volume of spray. The efficacy of these AI-WA nozzles being comparable to the double cone nozzles proves that enough penetration and coverage within the cane/weed canopy is obtained with these nozzles compared to floodjet nozzles. Jensen (1999) reported that herbicide efficacy is reduced with low volume air-inclusion nozzles. In Trial IV, the lower volume AI-WA (pale blue – AI110025VS) nozzle gave better control than the blue AI-WA; this may be explained by the relatively high volume (250 L ha⁻¹) used compared to lower volumes tested by Jensen. Furthermore, the finer droplets from the lower volume AI-WA nozzle may have been more efficient in wetting the weeds particularly Digitaria horizontalis (Jensen 1999). The similar efficacy recorded by the two AI-WA nozzles in Trial V may be explained by the predominance of broad-leaved weeds; in general both AI-WA nozzles would give satisfactory results for herbicide application in sugar cane.

CONCLUSION

Trials have revealed that air-inclusion nozzles may be used efficiently for herbicide application in sugar cane. For mechanical spraying, the blue colour-coded (0.3) nozzle has provided similar level of control to the standard flat fan nozzles delivering the same volume of spray. For Knapsack sprayers, AI-WA nozzles would be more appropriate as they have been found to have the same efficacy as the standard double hollow cone jet nozzles. Furthermore the AI-WA nozzles reduce significantly the volume of spray; the two AI-WA (AI110025VS and AI11003VS) nozzles tested used between 250 and 350 L ha⁻¹. The use of these air-inclusion nozzles will reduce risk of herbicide drifts during application in sugar cane more particularly in the vicinity of susceptible foodcrops.

ACKNOWLEDGEMENTS

The authors would like to thank the Agronomists of sugar estates involved for facilities granted in the establishment of the trials and Roger Fayd’Herbe & Co. LTD for supplying the Air Bubble Jet nozzles. Grateful thanks are also due to the Director of MSIRI, for reviewing this paper.

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Air-inclusion nozzles for improved herbicide application in sugar cane. S Seeruttun, C Barbe and A Gaungoo

UPROOTING OF CANE STUBBLES BY MECHANICAL HARVESTERS

G Claite, V Rivière, E Jacquin and D Pyneeandee

Mauritius Sugar Industry Research Institute

ABSTRACT

Mechanized harvesting of sugar cane has been identified as one of the most important means of reducing production costs in Mauritius. However, gappy stands have been observed in some trials with this mode of harvesting, mainly attributed to stubbles being uprooted by base cutter blades. Effects of two settings (ground level and 3 cm above ground level) of the base cutter on the extent of gaps were evaluated in 2001 and 2002 on cane varieties R 570 and M 695/69. Gaps equal to or greater than 60 cm were measured 12 weeks after harvest. In situ stool profile studies were conducted in fields that have been mechanically harvested for three years or more. Soil was excavated around the stool to observe the position and record the depth at which new shoots emerge. The root distribution was also studied. When base cutter blades were placed at ground level, the level of gaps with variety M 695/69 compared to variety R 570 increased by 2.7% and 5.8% in 2001 and 2002 respectively. With the other base cutter setting the increases were 0.9% and 1.5%. Observations of the stool profiles explain the difference in the behaviour of these two varieties. The position of emergence of new shoots, the depth of regrowth and the root distribution, which were studied also for varieties M 1658 / 78 and M 1176 / 77, are the main factors that contribute to uprooting of stubbles.

Keywords: base cutter, gaps, stool profile, lodging, stool tipping, shoot emergence

INTRODUCTION

After a first attempt in the mid 1970’s, mechanized harvesting of sugar cane was reintroduced in 1989 when some large producers were faced with a labour shortage. There was concern on the possible adverse effects of this mode of harvest on the sugar cane, namely a yield reduction in ratoons. Trials were thus laid down to compare cane growth and yield of manually harvested plots to those harvested mechanically. In addition to a depressive effect on growth of cane observed in some trials (MSIRI 2001), mechanized harvest by chopper harvesters was thought to be also responsible for death of stubbles, resulting in gappy stands.

Lately there have been apprehensions that ACP sugar producing countries would no longer benefit from the preferential sugar price under the WTO rules concerning liberalization of world trade. Ways and means to reduce production costs so as to be competitive on the World Market price have to be found. As labour represents about 60% of the production costs of sugar in Mauritius, mechanization of labour intensive field operations, mainly harvest, was perceived as one of the most important means to reduce production costs.

As from 2001, a Voluntary Retirement Scheme (VRS) was proposed to agricultural workers with the result that all producers had to resort further to mechanized harvest. The percentage area harvested mechanically which has increased gradually since 1990 to 2001 (Figure 1) was subject to a major increase in 2002, when 21.9% of the total weight of cane (19% of the area harvested) were harvested mechanically, mainly by chopper harvesters.

In 2001, research on mechanized harvest was reoriented towards the identification of causes of cane losses, namely through the extractor fans of chopper harvesters and damage to cane stubble by base cutters, and ways to reduce such losses. This paper highlights the identification of the causes of gappy stands after mechanized harvest in cane varieties R 570 and M 695/69, the predominant varieties harvested mechanically (Figure 2).
Figure 1  Evolution of mechanized harvest in Mauritius (1990 – 2002)

Figure 2  Varieties harvested mechanically in 2002

- Others 23%
- R 570 45%
- M 1176/77 9%
- M 695/69 16%
- M 1658/78 7%
MATERIALS AND METHODS

Base cutting height and its effect on regrowth of cane stubbles

Two trials were initiated at Deep River Beau Champ SE to evaluate the effect of different settings of the base cutter on the emergence of new shoots. Cane varieties M 695/69 and R 570 were chosen as they represent 32% and 30% of the total amount of cane harvested mechanically on this estate.

The chopper harvester was fitted with new blades on the base cutter to ensure a clean cut and to avoid damaging the stalks and cane stubbles. The harvester operator was instructed to set the base cutter so as to cut cane at two different heights namely:

- at ground level
- 3 cm above ground level.

The experimental plot comprised six cane rows over the whole length of the field (170-180 m). Each treatment was replicated five times. Twelve weeks after harvest gaps equal to or greater than 60 cm were measured. The total length of gaps was recorded and expressed as a percentage of the plot size.

Examination of stool profiles

Stool profiles were carried out in commercial fields that had been harvested mechanically for three consecutive years or more. The scope of this investigation was extended to varieties M 1658/78 and M 1176/77. Soil was removed around the cane stubbles to observe where new shoots emerged after harvest. The depth of regrowth, defined as the height from ground level to the point of emergence of the lowest new shoot, was recorded. The root system was examined to assess its distribution. Thirty cane stubbles were studied in each field.

RESULTS AND DISCUSSION

Effect of height of base cutter

The total length and percentage gaps resulting from the two base cutting heights after 2001 and 2002 harvests for the two varieties under test are given in Table 1.

<table>
<thead>
<tr>
<th>Base cutter settings</th>
<th>M 695/69</th>
<th>R 570</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gap length m</td>
<td>% Gaps</td>
</tr>
<tr>
<td>Ground level</td>
<td>73.2</td>
<td>131.5</td>
</tr>
<tr>
<td>3 cm above ground level</td>
<td>29.8</td>
<td>37.1</td>
</tr>
<tr>
<td>L.S.D (5%) ±</td>
<td>37.2</td>
<td>80.0</td>
</tr>
</tbody>
</table>

Cane variety M 695/69 is obviously very sensitive to the height of the base cutter. It is characteristically high yielding and very prone to lodging (falling over) and stool tipping (falling over with part of the root system tipped out of the ground). Lodging and stool tipping can occur both at right angles and parallel to the cane row. When at right angle and parallel to the cane row in the direction of travel of the harvester, the lodged stalks are not uprooted. However when found in the cane row and opposite the direction of travel of the harvester, the lodged stalks are uprooted by the feed rollers of the harvester. With stool tipping, whatever the case, the base cutter blades, especially when placed at ground level, were found to rip out sections of or whole stalks and uproot the rhizome. The significant increase in gaps of 2.6% between the two positions of the base cutter in 2001 was mainly attributed to stool tipping. The situation worsened in 2002 when lodging and stool tipping were more pronounced after the passage of cyclone Dina. In that year the difference between the two
treatments rose to 6%. In 2001 and 2002 the presence of gaps with cutting blades positioned three centimetres above ground level was due to some stool tipping and lodged stalks. On the other hand, the erect cane variety R 570 showed no marked difference between the two base cutter settings in the two-year test. Only an increase of 0.8% in the extent of gaps was noted between the two settings in 2001. The uprooting of stools was mainly attributed to the undulating nature of the field in both cases. With the cyclone event in 2002, the extent of gaps increased by 1% with the base cutter set at ground level. As the plant was at an early stage of growth during the cyclone, the stalks did not fall over. This increase was mainly due to the undulating soil surface. With the base cutter set three centimetres above ground level, no marked increase was observed in 2002. It became evident that some factors, found below the surface, were responsible for this difference between the two varieties.

Study of stool profiles

Emergence of new shoots, depth of regrowth and root distribution

The mode of emergence of new shoots from varieties M 695/69 and R 570 respectively are illustrated in Plates 1 and 2. For M 695/69, all shoots originate high up in the stool. The modal depth of regrowth of new shoots was 10 cm. The root system was poor and superficial. The roots were confined to the top 10 cm and had the tendency of spreading laterally.

These features resulted in weakening the anchorage of the plant. In combination with large crop size and wind, lodging and stool tipping may result. This explains the greater extent of gaps observed for this variety in the basecutting trials above. For variety R 570, there were also some shoots emerging from below the stool giving a greater modal depth of regrowth (16 cm). Its roots were more abundant and were found deeper in the soil profile. This resulted into a better plant anchorage and therefore less prone to being uprooted. The emergence of new shoots for varieties M 1176/77 and M 1658/78 is shown in Plates 3 and 4. The modal depths of regrowth for these two varieties were 15 and 10 cm respectively. The root system for M 1176/77 was abundant and found deeper in the soil profile whereas that of M 1658/78 was confined to the top 10 cm and tended to spread laterally. These features led to the conclusion that M 1658/78 will behave similarly to M 695/69 whereas M 1176/77 will resemble more R 570. This is confirmed by the percentage gaps measured in the commercial fields under test – M 695/69 (18.9%), M 1658/78 (25%), R 570 (4%) and M 1176/77 (negligible).

Agnew (1998) reported that previous work undertaken by Australia’s Bureau of Sugar Experiment Stations has shown that increasing the planting depth together with hillling up significantly reduced
lodging by 30% to 40%. The effect of these two cultural practices is currently being investigated on the extent of lodging.

**Emergence of new shoots**

Plate 3 M 1658 / 78

Plate 4 M 1176 / 77

**CONCLUSION**

This study has shown that positioning of the base cutter is not the sole factor responsible for uprooting cane stubbles. Varietal characteristics, such as the mode of emergence of new shoots, the depth of regrowth and the anchorage system, are the main contributors to the extent of gaps in a field. New shoots originating from high up in the stool will weaken the plant’s anchorage resulting in lodging and/or stool tipping, thereby increasing the risk of uprooting. The effect of planting at greater depth together with hilling up is being investigated to reduce lodging and/or stool tipping.

**ACKNOWLEDGEMENTS**

The authors wish to express their gratitude to the Field Managers, Area Managers and Agronomists of Deep River Beau Champ, Médine and Mon Désert Alma sugar estates for providing facilities to undertake this work and the Director, MSIRI for reviewing this paper.

**REFERENCES**


ABSTRACT

The computer model GLEAMS (Groundwater Leaching Effects of Agricultural Management Systems) was used to predict the effects of management practices on runoff and agrochemical movement under sugar cane in Mauritius. Weather, soil and management data for four sites from different climatic zones, collected during the period 1990 to 1999, were used. Preliminary model calibration was satisfactory for runoff, erosion and fertilizer losses, but unsatisfactory for pesticide loss. Annual runoff was predicted to represent less than 5% of total rainfall, with erosion much lower than the tolerable limit of 11 t ha$^{-1}$ year$^{-1}$. This modelling exercise has also indicated that fertilizers are lost predominantly in the sediment form while herbicides are mainly lost through runoff. Trash blanketing has been shown to be a viable strategy for pollution control since it reduces fertilizer and herbicide losses.

Keywords: computer model, runoff, agrochemical movement, erosion, trash blanketing

INTRODUCTION

Sugar cane productivity in Mauritius cannot be maintained at its current level of about 70 t ha$^{-1}$ without resorting to the use of fertilizers and pesticides. At this level of productivity over 77,000 ha, an annual input of 10,000 t nitrogen, 5000 t phosphorus, 12,000 t potassium and 900 t herbicides is required island wide. It is unlikely that there will be a significant decline in the amount of agrochemicals used in the near future, since sugar production will need to be kept constant to meet actual export commitments. On the contrary, with the growing competition for land, the smaller area available will need to be more productive and this will be achieved through a more concentrated use of agrochemicals. Furthermore, fertilizer and pesticide usage are expected to increase in non-cane lands and in cane inter rows as more vegetables and staple food (mainly potatoes) will have to be produced to meet the increasing demand for food of an increasing population.

Environmental concerns have been expressed in recent years with regards to the pollution potential of agrochemicals applied to sugar cane fields. In that context, studies on the measurement and prediction of agrochemical movement under tropical sugar production were initiated in the super humid region of Mauritius (Anon 1998). Unfortunately, results from this project are only valid for the region and the years in which the measurements are made. Such measurements cannot be undertaken at numerous sites for financial reasons. The measured data would be more useful if they could be extrapolated in space and time. To this end, simulation modelling has to be used, and this paper presents the results of such a modelling exercise at field level.

MATERIALS AND METHODS

Simulation model

The simulation model GLEAMS – Groundwater Leaching Effects of Agricultural Management Systems - (Leonard et al. 1987) was used to predict the effects of management practices on runoff and...
Using the gleams model to predict the effect of management practices on runoff and agrochemical movement under sugar cane. This computer model was developed jointly by the United States Department of Agriculture (USDA) and University of Georgia. It has been specifically developed to consider the effects of climate, soil and management on surface and subsurface chemical export. The model consists of four parameter editor files, simulating the hydrology, erosion/sediment yield, plant nutrient and pesticide components respectively. The hydrology component can be simulated independently of the other three components while the erosion file needs the hydrology component for simulation. Nutrient and pesticide aspects can only be simulated once the hydrology and erosion components are complete.

Figure 1 GLEAMS water balance model

There are two climate data files that are required to run the hydrology parameter file: daily rainfall and mean temperature. Within GLEAMS, there is a water balance model that splits the incoming rainfall into the different components through which it is dissipated (Figure 1).

The erosion component is thus dependent on the runoff portion of the rainwater, since sediment transport is associated with surface water movement. The nutrient and pesticide components occur through three forms, namely:

1. dissolved in runoff water,
2. dissolved in deep percolation water, and
3. adsorbed to eroded sediment.

Input parameters

Four sites, in two climatic zones and with two degrees of stoniness were chosen for the modelling exercise (Table 1). Daily rainfall, mean temperature and other climatic data were obtained from weather stations at or close to the four sites for the period 1990–1999.

Table 1 Sites selected for modelling exercise

<table>
<thead>
<tr>
<th>Site</th>
<th>Annual rainfall mm</th>
<th>Soil family*</th>
</tr>
</thead>
<tbody>
<tr>
<td>St Avold</td>
<td>3320</td>
<td>Humic Ferruginous Latosol, (F1)</td>
</tr>
<tr>
<td>Côte D’Or</td>
<td>2880</td>
<td>Latosolic Brown Forest, (B2)</td>
</tr>
<tr>
<td>Solitude</td>
<td>880</td>
<td>Low Humic Latosol, Richelieu family (L1)</td>
</tr>
<tr>
<td>Médine</td>
<td>690</td>
<td>Latosolic Reddish Prairie, Médine family (P1)</td>
</tr>
</tbody>
</table>

* Source: Parish and Feillafé, 1965
Other important data inputs included soil physical and chemical properties, topography, crop characteristics and management practices. The characteristics of the chemicals used in the field were included in the nutrient and pesticide parameter files.

**Scenarios applied**

Three scenarios were applied:

1. Trash management
   - Changing from keeping the trash in every other inter row to a complete trash blanket.
2. Fertilizer management
   - Changing from a single application at planting or harvest to a split application of N fertilizer.
3. Herbicide management
   - Applying herbicides just before the onset of the rainy season.

**Calibration of GLEAMS model**

For higher confidence in the simulated data generated by the model, the latter needs to be calibrated against measured data. To this effect, measured data on runoff, erosion and agrochemical transport (Table 2) from Valetta for the 1997/98 cropping season were compared against modelled data for the same period for the Côte D’Or field. The two sites are of the same soil family, are subject to very similar climatic conditions and had similar slopes, thus making them comparable for model calibration purposes.

<table>
<thead>
<tr>
<th>Calibrated parameter</th>
<th>Runoff % rainfall</th>
<th>Erosion t ha(^{-1})</th>
<th>N kg ha(^{-1})</th>
<th>P kg ha(^{-1})</th>
<th>Diuron % applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted (Côte D’Or)</td>
<td>4.9</td>
<td>1.54</td>
<td>3.0</td>
<td>1.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Measured (Valetta)</td>
<td>5.2</td>
<td>1.75</td>
<td>2.7</td>
<td>0.9</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

**Model calibration**

The best agreement between measured and simulated data for the 1997/98 cropping season was obtained with runoff, amount of sediment eroded and N losses (Table 2). The model did not produce a good match for P and diuron losses with the parameters used. The calibration exercise needs to be refined for P and herbicides, but looks promising for prediction of runoff, erosion and N losses.

**Modelling of actual situation**

The model predicted that only a small proportion (less than 5%) of incoming rainfall is dissipated as runoff. In both climatic zones, crop uptake accounts for more than 1000 mm of the incoming rain water; this represents 40 and 90% of the rainfall in the super humid and sub humid zones respectively. Some 50% of the rainfall is lost as deep percolation in the super humid region (Figure 2). On average, some 2 to 3 tonnes of soil are eroded per hectare in the super humid region, but this amount becomes negligible (< 0.1 t ha\(^{-1}\)) in the sub humid region.

The model predicted that up to 18 kg N ha\(^{-1}\) and 3 kg P ha\(^{-1}\) would be lost in the superhumid region (Figure 3). Deep percolation and sediment loss account for most of the N movement while P is predominantly lost as sediment. Irrespective of climatic zone and soil type, only a small proportion of
the fertilizers applied, typically less than 2 kg N and 0.5 kg P ha\(^{-1}\) is lost through runoff water. As with soil erosion, there is very little fertilizer loss in the subhumid region, less than 1 kg N and 0.5 kg P ha\(^{-1}\). Predicted loss of diuron varied between 1\% of the amount applied at the wettest site (mainly in runoff water) and 0.4\% in the drier region.

**Figure 2** Partitioning of water and sediment losses

![Partitioning of water and sediment losses](image)

**Figure 3** Prediction of Nitrogen and Phosphorus losses (kg ha\(^{-1}\))

![Prediction of Nitrogen and Phosphorus losses](image)
Effect of trash blanketing

With trash blanketing, sediment losses would be reduced by 40% or more, while fertilizer losses would be reduced by 15 to 35% at the three sites where trash blanketing is not a normal practice (Table 3). Similar reductions in losses are expected for diuron at St Avold and Côte D’Or. Most of the reduction in fertilizer losses is through a reduction in the sediment form, while diuron losses are mainly reduced through runoff. These predictions concur with the measured data for Valetta in the 1997/98 season (Anon 1999) when trash lining over every interrow led to a decrease of some 40% compared to the normal practice of lining trash in every other interrow. However, more agrochemicals are moved in a different pathway since trash blanketing enhances percolation losses.

Table 3 Predicted reduction in losses (%) through runoff with trash blanketing

<table>
<thead>
<tr>
<th>Site</th>
<th>Sediment</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Diuron</th>
</tr>
</thead>
<tbody>
<tr>
<td>St Avold</td>
<td>38</td>
<td>15</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>Côte d’Or</td>
<td>69</td>
<td>35</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Médine</td>
<td>41</td>
<td>26</td>
<td>19</td>
<td>NA*</td>
</tr>
</tbody>
</table>

* N/A: Not applicable

Split fertilizer application scenario

There was no definite trend in the effects of split fertilizer application on N losses. Thus, a 10% increase is predicted for the St Avold site while a 9% decrease would occur for Côte d’Or. The reason for these completely different predictions lies in the rainfall distribution over the study period. In the case of St Avold, splitting the N application actually puts the second application in a wetter period in the wettest year (1995) and this consequently leads to greater losses overall. The opposite happened for Côte D’Or where the second application coincided with a drier period and thus led to lower losses.

Delayed herbicide application scenario

If the application of herbicides is delayed till the onset of the rainy season, the risks of losses are greatly increased. Losses of the most commonly used product, diuron, would increase by 46% for St Avold and by 224% for Côte D’Or.

CONCLUSIONS

The model GLEAMS can be used for scenario modelling of agrochemical losses, as its results generally concur with measured data. The herbicide parameters need to be refined to bring predictions on this component in line with measured data.

The modelling exercise has confirmed that sediment is the main pathway for fertilizer losses while herbicides move predominantly in the solution form (as runoff). It is a useful tool for soil conservation and pollution control; from the modelling results, it can be inferred that reducing sediment loss would best minimize fertilizer losses. This has further been shown to be achievable through trash blanketing. The latter has also been shown to be a viable strategy for reduction in herbicide losses through a reduction in runoff volume.

ACKNOWLEDGEMENTS

We thank the Director and colleagues at MSIRI for their support and collaboration. The contribution of field staff of Médine, Solitude, Britannia and Highlands in supplying data is gratefully acknowledged.
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CHARACTERIZATION OF ORGANIC POLLUTANTS IN
SEWAGE SLUDGE TO BE DISPOSED IN SUGAR CANE FIELDS
IN MAURITIUS

A Soobadar, G Umrit and KF Ng Kee Kwong

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ABSTRACT

The application of sewage sludge in sugar cane fields should represent the most sensible economic option for its disposal in Mauritius. However from the environmental viewpoint, the practice will need careful control because of the possible presence of organic pollutants in the sludge. These organic pollutants were characterized in sludge collected on 4 October 2000 at Cité Kennedy treatment plant, (a week after its release into the drying pond) and on 6 November 2000 at Saint Martin treatment plant. Sewage sludge and effluent from Saint Martin have in addition been further sampled on a daily basis during two one-month periods (October to November 2001 and September to October 2002) and analyzed.

Sludge samples taken monthly from the two sites showed no detectable levels of the generally reported prioritized pollutants, namely polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzo-p-furans (PCDFs), polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs). However 16 PAH compounds have been identified at trace levels, in sewage sludge sampled daily over the period October to November 2001 at Saint Martin treatment plant. In samples where PAHs have been identified, pyrene and fluoranthene were the most prominent compounds.

Keywords: organic contaminant, sewage sludge, agricultural re-use, environment.

INTRODUCTION

To protect the environment in Mauritius, the aims of the government with regards to sewage sludge disposal are to treat the sewage to render it of an adequate quality for the safe return of the effluent to the fresh water habitat and to dispose the sludge in an environmentally acceptable manner. Currently, with only one sanitary landfill at Mare Chicose catering for the whole island and which is expected to reach its saturation point by 2005, it is clear that alternative disposal routes for sewage sludge need to be identified, such as ocean dumping, incineration and agricultural re-use.

The application of sewage sludge to agricultural land as a substitute for fertilizers and as an amendment for improvement of soil physical properties is believed to represent the most sensible economic option for its disposal (Beck et al. 1995). Sludge however contains organic contaminants, which are perceived as being harmful to human health and the natural ecosystems on account of the high toxicity and carcinogenic properties of many of the organics (Chaney et al. 1991). Disposal of sewage sludge in sugarcane lands therefore requires careful and responsible management to avoid potential environmental and health problems. In this context as part of a large scale project initiated in 2000 on the disposal of sewage sludge in sugar cane fields, the organic pollutants in sewage sludge in Mauritius have been characterized.
MATERIALS AND METHODS

Sampling

Organic contaminants were characterized in sewage sludge coming from two treatment plants, namely Cité Kennedy and Saint Martin. The sewage sludge was collected in glass containers on 4 October 2000 at Cité Kennedy treatment plant, (a week after its release into the drying pond), and on 6 November 2000 at the Saint Martin treatment plant. Furthermore at Saint Martin, sludge and its effluent were sampled on a daily basis from 8 October to 9 November 2001, from 16 September to 18 October 2002, and on a two-hourly basis (effluent only) during a one-week period (18 March to 22 March 2002). The samples were stored at 4°C until chemical analysis. Interest was focussed on sludge at Saint Martin treatment plant because by the beginning of 2005, as much as 13 500 tons of sludge will be generated yearly by that plant.

Chemical analysis

A 20g sludge sample was soxhlet-extracted for 16 hours with 200 ml toluene, after which the extracts were subjected to a series of clean up procedures, starting with concentrated sulphuric acid and then with sodium chloride and potassium hydroxide. The organic phase was dried over sodium sulphate, rotary evaporated to two milliliters and exchanged into hexane. The extracts were further purified on an alumina/silica column and the analytes eluted with 20 ml dichloromethane/hexane mixture (1:4). The analyte fraction was preconcentrated in a rotary evaporator before evaporation to dryness under a gentle nitrogen stream, and brought up to one milliliter with hexane (US EPA, 1996).

One microlitre samples were analyzed using a gas chromatograph coupled to a mass selective detector, (GC-MSD). Data acquisition was conducted in the full scan mode. The minimum detectable limits (MDL) for surrogates using these methods were 10-25 µg kg⁻¹ sludge and 0.10-0.25µg l⁻¹ effluent.

RESULTS AND DISCUSSION

As a wide variety of organic compounds used in households and industry can find their way into sewage sludge via waste water treatment, the range of organic compounds detectable and which may be identified as a result of progress in analytical chemistry in recent years is extensive. However most of the organic pollutants present are rapidly degraded in soils and more importantly, they are not absorbed by plants (Smith, 1996). They are perceived as being harmful more often because of their unknown hazards to public health and environment. Current environmental concerns over the presence of trace organic contaminants applied to soils in sewage sludge arise from their potential to transfer to humans via groundwater (used as drinking water), and livestock ingestion.

Present research has nevertheless made it clear that the hazards associated with trace organics in sewage sludge may be reduced to the following few groups of contaminants due to their persistence in soils and known toxicological behaviour: organochlorine compounds, especially polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins/dibenzofurans (PCDDs / PCDFs), organochlorine pesticides, polycyclic aromatic hydrocarbons (PAHs), phthalates and surface active agents. Accordingly in the present study analysis of sludge and effluent samples was focussed on these prioritized organic contaminants.

None of the scan chromatograms of Cité Kennedy and Saint Martin sludges and effluent samples showed levels of PCDDs, PCDFs and PCBs equal to or above the minimum detectable limit. Generally these latter substances are released into the environment as contaminants or by-products associated with various anthropogenic processes involving the combustion of chlorinated compounds, such as cement kilns, waste incinerators and steel plants (Fielder et al. 1990). Since such industrial activities are not a common feature in Mauritius, this may explain the non-detectable limits of these organic compounds.
However, the 16 PAH compounds listed in Table 1 have been identified at trace levels only in the sewage sludge collected daily during the two one-month periods sampling at Saint Martin treatment plant. The PAHs in the environment are derived mainly from combustion of fossil fuels, but they are rapidly and extensively metabolized so that significant amounts of this group of compounds are not expected to be present in sewage sludge (Sutherland et al. 1995). In samples where PAH congeners have been occasionally detected, pyrene and fluoranthene were the most prominent compounds compared to the higher molecular weight PAHs (e.g. benzo[a]pyrene and benzo[ghi]fluoranthene).

**Figure 1** Chromatogram showing the trace presence of fluoranthene and pyrene in sewage sludge collected at Saint Martin treatment plant.

![Chromatogram showing the trace presence of fluoranthene and pyrene in sewage sludge collected at Saint Martin treatment plant.](image)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Detection Frequency (n = 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>3</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>4</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>2</td>
</tr>
<tr>
<td>Fluorene</td>
<td>18</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>23</td>
</tr>
<tr>
<td>Anthracene</td>
<td>20</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>29</td>
</tr>
<tr>
<td>Pyrene</td>
<td>27</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>11</td>
</tr>
<tr>
<td>Benzo[j]fluoranthene</td>
<td>3</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>7</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>9</td>
</tr>
<tr>
<td>Benzo[b]fluorene</td>
<td>5</td>
</tr>
<tr>
<td>Benzo[ghi]fluoranthene</td>
<td>1</td>
</tr>
<tr>
<td>Perylene</td>
<td>1</td>
</tr>
<tr>
<td>Chrysene</td>
<td>9</td>
</tr>
</tbody>
</table>
The extremely low concentrations of pyrene and fluoranthene present in sewage sludge at Saint Martin is illustrated in Figure 1.

Perez et al. (2001) also found pyrene, fluoranthene, anthracene and phenanthrene to be the most abundant PAHs in sewage sludge. Saint Martin treatment plant receives a significant amount of domestic sewage water and charbroiling accounts for a major source of fluoranthene and pyrene in households. Fluoranthene has been also reported to be the most abundant individual compound in sludge in the United Kingdom (Wild et al. 1991). Moreover other studies on PAH compounds have shown that 5-ring PAHs originate mostly from industrial discharges (Alloway et al. 1993). A PAH surrogate, 2-fluorobiphenyl spiked in sludge at a concentration of 0.35µg g\(^{-1}\) has provided an estimation of the concentration of the identified PAH compounds. As the peak areas of fluorene and benzo[a]pyrene were three and five times respectively lower than that of the surrogate in Figure 2, the concentration of PAH would not exceed 120 mg kg\(^{-1}\) in Mauritius.

**Figure 2** Comparison of the peak areas of a surrogate polycyclic aromatic hydrocarbon (PAH) compound, 2-fluorobiphenyl (0.35 µg g\(^{-1}\)), and two identified PAHs, benzo[a]pyrene and fluorene, in sludge samples from Saint Martin Treatment plant.
It has been reported that sewage sludge can also be contaminated with a wide array of other potentially toxic organic compounds namely, monocyclic aromatics, linearalkylbenzylsulphonates, halogenated aliphatics and phenols (Cameron et al. 1997). So far none of these groups of compounds have been detected in the analyzed sludge and effluent samples. On the other hand, as illustrated in Figure 3, a number of pharmacological compounds such as azepine, barbatusol, benzocinnoline and naphtoquinone have been identified in sludge samples at Saint Martin and Cité Kennedy.

**Figure 3** Chromatogram showing the main organic compounds detected in Saint Martin sewage sludge

CONCLUSION

Based on this study, sewage sludge in Mauritius would not contain high levels of PAH compounds whereas the other prioritized organic pollutants would be completely absent. It can therefore be inferred that application of sewage sludge on agricultural land in Mauritius will provide a safe disposal route for the increasing amounts of sewage sludge which will be generated on the island.

REFERENCES


LEACHING AND UPTAKE OF HEAVY METALS FROM SOILS AMENDED WITH SEWAGE SLUDGE UNDER RAINFED SUGAR CANE IN MAURITIUS.

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Mauritius Sugar Industry Research Institute

ABSTRACT

Sewage sludge when added to arable land can substitute for mineral fertilizers and improve soil physical properties. However, the presence of heavy metals in sewage sludge and their accumulation in soils would raise concern about possible toxicity to the sugar cane and potential contamination of groundwater sources. Lysimeter studies at Réduit (annual rainfall <1500 mm) and at Belle Rive (annual rainfall > 3500 mm) initiated to investigate the leaching of heavy metals: cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn); from soils receiving sewage sludge at the rate of 0, 20 and 60 t ha\(^{-1}\) provided evidence to show that the heavy metals would not be a hazard to the environment and would not affect the quality of the sugar cane. Thus data obtained during the 2000-2001 and 2001-2002 crop seasons showed that the concentrations of Cd, Cr, Cu, Hg, Ni, Pb and Zn in the leachates and in the cane at harvest were hardly influenced despite the application of 60 t ha\(^{-1}\) of sludge.

Keywords: sewage sludge, groundwater pollution, toxicity, sugar cane

INTRODUCTION

With the aim of Government to extend sewage system by providing pipe collection of sewage from each household unit, commercial property and industrial enterprise, sewage sludge production from wastewater treatment plants in Mauritius will rise to about 15 000 t yr\(^{-1}\) in 2005 and is expected to further increase to approximately 35 000 t in 2015. Possible disposal routes for such waste materials are landfilling, incineration, ocean dumping and agricultural re-use. Agricultural re-use has been found elsewhere (e.g. Beck et al., 1995) to represent, from the environmental and economic viewpoint, the most sensible disposal option. Indeed, as reported by Higgins (1984) sewage sludge when applied to arable land increased agricultural productivity by supplying nutrients, especially nitrogen (N) and phosphorus (P) to crops, and its high organic matter content also makes it useful as a soil conditioner (Korentajer, 1991). The agronomic benefits of sewage sludge application to crops are well documented and are the basis for its successful utilization elsewhere (Lindsay and Logan, 1998). However, as reviewed by Berti and Jacobs (1998), sewage sludge may also contain heavy metals such as Cd, Cr, Cu, Hg, Ni, Pb and Zn that are of environmental concern. Continuous application of sewage sludge on land will result in the accumulation of heavy metals in soils at toxic levels to plants and in the contamination of food and forage crops (Bevacqua and Mellano, 1994).

To adequately measure the net benefits of using sewage sludge as a fertilizer for sugar cane, possible effects that the trace metals in sewage sludge may have on sugar cane and on groundwater quality through their leaching down the soil profile must be considered and weighed against the expected benefits. Numerous studies have been carried out on the leaching and plant uptake of heavy metals in sludge amended soils of the temperate regions (e.g. Berti and Jacobs, 1998; McBride et al., 1999). The findings are not necessarily applicable to soils of the humid tropics such as those in Mauritius. For this reason, as part of a large scale project to determine the fertilizer equivalence of sewage sludge for sugar cane, lysimeter studies were initiated in Mauritius to investigate the leaching and uptake of heavy metals by rain-fed sugar cane grown in soils amended with sewage sludge.
MATERIALS AND METHODS

The studies were conducted in concrete lysimeters (200 cm long by 150 cm wide by 100 cm deep) at two sites, namely Réduit and Belle Rive. Réduit is located in an area receiving an average annual rainfall of 1500 mm while Belle Rive has a mean annual rainfall of 3500 mm and is representative of the super-humid zone of Mauritius. Sewage sludge was applied to the lysimeters at both sites at three rates, namely, 0, 20 and 60 t ha\(^{-1}\). On the assumption that 70% of the total N present in the sludge would be available to the plant, analysis of the sludge indicated that the application of 20 t sludge ha\(^{-1}\) would supply the equivalent of 140 kg N ha\(^{-1}\), the rate of N which sugar cane on average receives every year when mineral fertilizers are used. Each sludge treatment was replicated twice in a completely randomised block design. The sewage sludge used in this study was pre-treated through aerobic digestion at the Cité Kennedy wastewater treatment plant. The plant receives wastewater mainly from domestic sources and from a neighbouring hospital. The nutrient content and the total concentration of heavy metals in the sludge are given in Table 1.

Table 1 Nutrient and heavy metals content of sewage sludge applied in 2000 and in 2001 to sugar cane in lysimeters at Belle Rive and Réduit

<table>
<thead>
<tr>
<th>Element (dry weight basis)</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% N</td>
<td>2.62</td>
<td>7.02</td>
</tr>
<tr>
<td>% P</td>
<td>0.61</td>
<td>1.06</td>
</tr>
<tr>
<td>% K</td>
<td>0.06</td>
<td>0.11</td>
</tr>
<tr>
<td>Heavy metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg kg(^{-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>2.40</td>
<td>4.0</td>
</tr>
<tr>
<td>Cr</td>
<td>310.50</td>
<td>133.2</td>
</tr>
<tr>
<td>Cu</td>
<td>139.90</td>
<td>428.4</td>
</tr>
<tr>
<td>Hg</td>
<td>Nd</td>
<td>2.1</td>
</tr>
<tr>
<td>Ni</td>
<td>117.60</td>
<td>111.7</td>
</tr>
<tr>
<td>Pb</td>
<td>120.40</td>
<td>231.3</td>
</tr>
<tr>
<td>Zn</td>
<td>347.40</td>
<td>1294.2</td>
</tr>
</tbody>
</table>

Nd: not detected

Germinated one-eyed cuttings of sugar cane, variety R570 at Réduit and variety M3035/66 at Belle Rive, were planted in a single row 200 cm long in the middle of the lysimeters. The soils were found to contain adequate amounts of P and silicon (Si) whereas potassium (K) was applied at the rate of 150 kg KCl ha\(^{-1}\) in the furrows at the time of planting the sugar cane. Prior to planting of the sugar cane in October 2000, sewage sludge was applied in the furrows. The plant cane crop was harvested in June 2001. Sewage sludge was again applied in November 2001 by surface banding along the ratoon cane rows. The cane was afterwards harvested in May 2002. At each harvest, trash, cane tops and cane stalks were sampled for determination of their total heavy metals content.

During each rainfall event the leachates from each lysimeter were collected in a calibrated tipping bucket fitted with a counter. The number of tips registered provided an estimate of the volume of water leached from each lysimeter. When the tipping bucket was full, it tipped over a splitter thereby enabling a fraction of the leachate to be sampled and collected into a glass bottle. The concentration of heavy metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) in leachates as well as in plant materials, following digestion with aqua regia as outlined by Rowell (1994), was measured using a Varian AA10BQ Atomic Absorption Spectrophotometer fitted with a Graphite Tube Atomizer/or Cold Vapour Atomizer.
RESULTS AND DISCUSSION

Heavy metals in drainage water

The concentration of trace metals Cd, Cr, Cu, Hg, Ni, Pb and Zn in water draining at one metre depth in lysimeters were mostly below detection limits even when sewage sludge was applied at 60 t ha\(^{-1}\). Only trace amounts of Zn (\(<\ 0.15\ \text{mg L}^{-1}\)) have been detected in leachates at Réduit and Belle Rive during the 2000–2002 period (figure 1).

Figure 1 Concentration of zinc in water draining at one metre depth in lysimeters cropped with sugar cane receiving 0 and 60 t sludge ha\(^{-1}\) at Réduit & Belle Rive

The data obtained during the two-year study period concurred with observations elsewhere (e.g. Higgins, 1984) and provided evidence to show that if sewage sludge is applied to soils under sugar cane cultivation in Mauritius there will be little risk of contamination of groundwater by heavy metals. The low concentration of Zn in leachates was consistent with the findings of McGowen and Basta (2001) who found that Zn was more mobile compared to other heavy metals whose mobility down the soil profile were hampered as a result of their sorption to the organic fraction. Moreover, Kretzschmar and Voegelin (2001) reported that heavy metals released from sewage sludge would in the long term be subsequently immobilized by readsorption to the soil solid phases or by the formation of new solid products such as hydroxides, hydrotalcites, or phyllosilicate structures.
The absence of heavy metals observed in leachates may also be attributed to soil pH. As indicated by McBride (1994), soil pH is the key parameter regulating metal behaviour in the soil systems. With the solubility of heavy metals and their mobility decreasing with increasing pH, the relatively high pH values (6.4-8.4) of the soil leachates at Belle Rive and Réduit would help to account for the extremely low concentration or absence of heavy metals found.

**Uptake of heavy metals**

As shown in Figure 2 the concentrations of heavy metals in the sugar cane plant harvested in 2002 in the treatment receiving 60 t ha⁻¹ of sewage sludge was not significantly higher than that in the control plot despite repeated applications of 60 t sludge ha⁻¹ over two consecutive years (Table 2). The immobile nature of the heavy metals as discussed above also explained the observed poor bioavailability of heavy metals to sugar cane.

**Table 2** Heavy metals applied to sugar cane through 60 t ha⁻¹ sludge in two consecutive years

<table>
<thead>
<tr>
<th>Metal</th>
<th>kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>21.20</td>
</tr>
<tr>
<td>Cu</td>
<td>7.50</td>
</tr>
<tr>
<td>Ni</td>
<td>3.50</td>
</tr>
<tr>
<td>Cr</td>
<td>7.30</td>
</tr>
<tr>
<td>Pb</td>
<td>4.90</td>
</tr>
<tr>
<td>Cd</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Further repeated applications of the sewage sludge is not expected in the long term to cause any appreciable rise in the concentration of heavy metals in the sugar cane plant. Indeed heavy metals such as Cd (the heavy metal posing the gravest danger because of its ability to move up the food-chain and...
adversely affect human health), as illustrated in figure 3, are not only present in sewage sludge but may also be encountered in mineral fertilizers, albeit in higher concentrations than in sewage sludge. Repeated yearly application of phosphate fertilizers and thus of Cd to soils did not, as shown in figure 4, result in higher concentration of Cd in sugar cane than when no phosphate fertilization was carried out during as long as half a century.

**Figure 3** Concentration of cadmium in sewage sludge and fertilizers

**Figure 4** Concentration of cadmium in sugar cane grown on soils receiving repeatedly every year for more than 50 years 350 kg ha\(^{-1}\) triplesuperphosphate at Réduit and Belle Rive
CONCLUSION

The data obtained during this study demonstrated that leaching of heavy metals down the soil profile to reach the ground water sources should not be an impediment to the disposal of sewage sludge in sugar cane fields. Indeed Zn was the only element detected in leachates and even then its concentration remained well below the United States Environmental Protection Agency maximum contaminant levels in drinking water. The application of as much as 60 t ha\(^{-1}\) of sewage sludge will not even in the long term impair the quality of the sugar cane crop.

REFERENCES


PERFORMANCES D'ABATTAGE DU CERF RUSA (CERVUS TIMORENSIS RUSSA) DANS LES ILES MASCAREIGNES

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1 Centre de Coopération internationale en Recherche agronomique pour le Développement, Pôle Elevage, 7 Chemin de l’IRAT, 97410 Saint Pierre de la Réunion.
2 The Mauritius Deer Farming Co-operative Society Ltd, 2 Avenue d’Epinay, Quatre Bornes, Maurice.

RESUME

Les résultats d'abattage du cerf rusa à l'île Maurice et à la Réunion ont été étudiés sur plusieurs années. Les poids des carcasses sont supérieurs à l'île Maurice (29,72 ± 3,88 vs. 26,73 ± 4,78 kg à la Réunion), vraisemblablement en raison d'une complémentation alimentaire distribuée lors des périodes de pénurie fourragère, liée à un âge d'abattage plus tardif. Un effet de la saison apparaît seulement à l'île Maurice, où les poids de saison fraîche sont supérieurs de 1 kg à ceux de saison chaude. Au cours des années, ces poids sont restés quasiment constants à la Réunion. En revanche, ils ont fluctué à l'île Maurice, où une diminution a été enregistrée en 1997 et 1998, vraisemblablement due à un âge d'abattage plus précoce pour satisfaire aux besoins du marché. Une remontée des poids a été observée dès 1999, où une très forte sécheresse a imposé la sacrification d'animaux adultes et une complémentation alimentaire plus élevée des troupeaux d'abattage pour pallier le manque de fourrage. Les performances d'abattage des cerfs rusa à l’île Maurice, tous sexes confondus, sont proches de celles des mâles abattus dans le cadre d’une étude conduite en Nouvelle-Calédonie, où l’exploitation des animaux est conduite selon un modèle plus extensif. Il existe donc sur ces deux îles une marge d’amélioration potentielle, qui à la Réunion peut passer par une modification des systèmes d’élevage traditionnellement suivis.

INTRODUCTION

Les îles Mascareignes, Maurice et la Réunion, abritent toutes les deux d'importantes populations de cerfs rusa (Cervus timorensis russa) depuis leur introduction au dix-septième siècle par des navigateurs hollandais. Le nombre de biches reproductrices maintenues en élevages y est respectivement d'environ 4 500 et 2 000, amenant sur le marché une production annuelle de venaison proche de 40 t à l'île Maurice et de 25 t sur l'île de la Réunion. A la Réunion, les animaux en élevage constituent plus de 95 % du cheptel de l'île, alors qu'à l'île Maurice le cheptel le plus important (environ 60 000 animaux) est dans les "chassés" mauriciens. La Réunion bénéficie depuis 1998 d'un abattoir aux normes européennes par lequel passent tous les animaux d'élevage. A l'île Maurice, les cerfs d'élevage sont abattus d'octobre à mai, directement sur la ferme, puis envoyés à l'abattoir local pour l'éviscération et l'inspection par les services vétérinaires, les animaux des chassés assurant la couverture en venaison lors de la période de la chasse, soit de juin à septembre. La présente étude vise à comparer les performances d'abattage du cerf rusa à partir des données collectées sur ces deux îles, et à les comparer avec les résultats obtenus lors de la campagne d'abattage 1994 de daguets en Nouvelle-Calédonie, rapportés dans l'étude de Le Bel et al. (1997).

MATERIEL ET METHODES

et confiés à l’Etablissement Départemental de l’Elevage. Les données sont traitées statistiquement selon les procédures Global Linear Model du logiciel de statistique SAS.

RESULTATS

Les résultats d’abattage des cerfs dans les Mascareignes sont présentés dans le tableau I. Le poids moyen des carcasses de cerfs mauriciens apparaît supérieur à celui des cerfs réunionnais \( P < 0,001 \). A l’île Maurice, la saison a un effet significatif sur le poids carcase (supérieur en saison fraîche, \( P < 0,001 \)) ; il existe également un effet significatif de l’année (\( P < 0,001 \), résultats non présentés), avec une chute marquée des poids d’abattage en 1997 et en 1998, plus marquée cette dernière année : les poids en 1998 sont inférieurs à 28,5 kg quelle que soit la saison, alors qu’ils sont systématiquement égaux ou supérieurs à 30 kg les années 1995, 1996, 1999 et 2000. Une interaction significative (\( P < 0,001 \)) entre l’année et la saison réduit la différence entre les résultats d’abattage des saisons des deux années 1997 et 1998. De tels effets n’apparaissent pas à la Réunion.

Tableau I Résultats d’abattage du cerf rusa dans les îles Mascareignes, en saison chaude (du 15 novembre au 15 mai) et en saison fraîche (du 15 mai au 15 novembre)

<table>
<thead>
<tr>
<th>Période d’étude</th>
<th>Île Maurice</th>
<th>Île de la Réunion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nombre d’abattages (*)</td>
<td>1998</td>
<td>127</td>
</tr>
<tr>
<td>Nombre d’animaux abattus (**)</td>
<td>10 270</td>
<td>2 767</td>
</tr>
<tr>
<td>Poids carcasse moyen (kg)</td>
<td>29,72 ± 3,88</td>
<td>26,73 ± 4,78</td>
</tr>
<tr>
<td>Poids carcasse moyen en saison chaude (kg)</td>
<td>29,42 ± 3,54</td>
<td>26,78 ± 5,50</td>
</tr>
<tr>
<td>Poids carcasse moyen en saison fraîche (kg)</td>
<td>30,45 ± 4,51</td>
<td>26,67 ± 3,79</td>
</tr>
</tbody>
</table>

(*) Nombre de fois où des animaux ont été envoyés à l’abattoir.
(**) Nombre total d’animaux envoyés à l’abattoir et dont le poids a été récolté.

DISCUSSION

A l’île Maurice comme à la Réunion, les animaux destinés à l’abattage sont conduits en un troupeau bien différencié dès le sevrage, mélangant les deux sexes, et auquel est affecté un parcellaire de l’exploitation précis. Leur élevage se fait sur des parcelles de graminées tropicales, selon le principe du pâturage tournant : le rythme de rotation dépend de la croissance de l’herbe, et varie selon les saisons.

A l’île Maurice, les éleveurs distribuent systématiquement à leurs animaux un complément alimentaire à base de sous-produits de la canne à sucre (mélabag), pendant la période de pénurie et de moindre qualité fourragère correspondant à la saison fraîche, mais également en fin de saison chaude, de mars à mai, où la MDFCSL a des difficultés à trouver des animaux de bonne conformation. C’est durant la saison fraîche que les poids d’abattage sont supérieurs : la période de commercialisation de la venaison des animaux d’élevage qui débute en octobre concerne les animaux les mieux conformés, soit les mâles plus lourds et dominants dans le troupeau d’abattage, soit les animaux trop légers lors de la saison d’abattage précédente et que les éleveurs ont gardé une saison supplémentaire. En outre, en début de saison fraîche, qui correspond à la fin de la période d’abattage, une complémentation alimentaire plus poussée assure une meilleure conformation des animaux destinés à être abattus.

On n’observe pas sur l’île de la Réunion de différence dans les poids d’abattage en fonction de la saison. En réalité, en raison à la fois d’une forte pression commerciale imposant aux éleveurs un abattage des animaux très jeunes et de l’absence d’une complémentation alimentaire aux animaux d’abattage, les poids d’abattage, de 3 kg inférieurs à ceux relevés à l’île Maurice, restent très faibles et ne permettent pas d’extérioriser le potentiel du cerf rusa.
Pourtant, différentes études ont montré que le potentiel de croissance de l'espèce était élevé, et qu'avec une complémentation adaptée les poids d'abattage de mâles âgés de moins de 15 mois pouvaient atteindre des valeurs proches ou supérieures à 35 kg (Grimaud et Chardonnet, 1989; Woodford et Dunning, 1990; Bheekhee et al., 2001). En Nouvelle-Calédonie, les 1053 cerfs abattus en 1994 étaient pour 93 % d'entre eux des mâles entiers de un an dont le poids moyen carcasse a été de 28,4 ± 0,3 kg (LeBel et al., 1997). Les conditions d'abattage sont similaires à celles de la Réunion, puisqu'un abattoir aux normes européennes assure l'abattage des cerfs depuis 1991. En revanche, les conditions d'exploitation extensive des animaux différencient des celles observées dans les élevages des îles Mascareignes : avec des chargements très faibles, de l'ordre de 3 cerfs à l'ha, les animaux sont conduits sur parcours en pâturage continu et les manipulations y sont occasionnelles (LeBel et al, 1997). L'abattage y concerne aussi bien des jeunes daguets et bichettes que des animaux adultes, ce qui a conduit les organismes d'encadrement de la filière à une rémunération à l'éleveur qui diffère selon l'état de la carcasse de l'animal, celle-ci étant dévalorisée si elle correspond à un animal âgé ou si son poids est inférieur à 23 kg ou supérieur à 45 kg (LeBel et al., 1997). Malgré une latitude de la Nouvelle-Calédonie proche de celle des Mascareignes, ces derniers auteurs y distinguent 3 saisons climatiques et observent que c'est durant la saison fraîche, correspondant de mai à août, que les poids d'abattage sont supérieurs. Cette période, qui correspond à ce qui a été défini l'île Maurice comme le début de la saison fraîche, est celle où le fourrage de nature tropicale est encore présent en quantité avec une valeur nutritive qui n'a pas encore décliné.

Que ce soit en Nouvelle-Calédonie ou dans les îles Mascareignes, peu de données sont disponibles sur les animaux d'élevage permettant le calcul d'un rendement à l'abattage. D'expérimentations en milieux contrôlés, LeBel et al. (1997) déduisent que les meilleurs rendements sont obtenus avec des jeunes daguets de 1 an, et atteignent la valeur de 58 %. Le suivi de jeunes daguets et bichettes dans un élevage à la Réunion ne montre pas de différence dans ces rendements en fonction du sexe de l'animal, mais restent inférieurs à la valeur précédente (56,4 %). Bheekhee et al. (2001) s'appuient quant à eux sur une valeur moyenne de 55 % pour effectuer une simulation économique visant à comparer trois formules différentes de complémentation alimentaire sur des animaux des deux sexes. LeBel et al. (1995) ont montré que la castration des jeunes mâles vers 10-12 mois entraînait une augmentation du rendement carcasse de 1 point, tout en se traduisant par une perte de poids vif de l'ordre de 3 kg à 24 mois et de 6 kg à 30 mois. Chez ces animaux de 2 ans et plus, la castration, compatible avec la fourniture de carcasses de bonne qualité bouchère, permet de fournir une viande plus tendre et moins foncée qu'un abattage tardif. Les meilleurs rendements rapportés dans la littérature proviennent en effet des études de Woodford et Dunning (1990), qui notent des valeurs de 60 % sur des animaux de 24 mois, amenant à des poids carcasses moyens de 47-50 kg. Cet abattage d'animaux tardifs pourrait être une voie pour une meilleure valorisation génétique du cerf rusa, mais elle impose de nouvelles pratiques d'élevage et nécessitent notamment une adaptation du parcellaire des exploitations, à moins de pratiquer un système d'embouche à l'aune non consommateur de foncier. Si le cerf rusa peut s'adapter à des conditions de claustration (Grimaud et Chardonnet, 1989), une telle politique d'élevage implique des modifications profondes dans la perception de l'exploitation des cerfs. Cependant, sur l'île de la Réunion, s'est développé à proximité du littoral un modèle intensif d'élevage sous forte contrainte foncière. Mais, essentiellement en raison d'une mauvaise technicité des éleveurs qui se sont lancés sans formation particulière dans une spéculation qui était nouvelle pour eux, ce type d'élevage a montré ses limites. De telles observations ont conduit à préconiser une exploitation semi-intensive du cerf rusa, avec des chargements de 8 biches à l'hectare, qui pourrait répondre au besoin d'accroissement de la production de viensaison sur cette île (Grimaud et Chardonnet, 1989; Woodford et Dunning, 1990; Bheekhee et al., 2001).

CONCLUSION

L'élevage du cerf rusa dans les îles Maurice et de la Réunion de l'archipel des Mascareignes se fait exclusivement au pâturage, et est donc soumis à des conditions climatiques qui vont influer sur la quantité et la qualité de fourrage disponible. Les meilleurs résultats des éleveurs mauriciens, proches de ceux enregistrés en Nouvelle-Calédonie, sont en partie dus à la distribution d'un complément alimentaire à base de produits issus de l'industrie sucrière, et permettent de mettre sur le marché des carcasses d'un poids proche de 30 kg. A la Réunion, les poids des animaux abattus inférieurs d'environ
Performances d'abattage du cerf rusa (*Cervus timorensis russa*) dans les îles mascareignes. *P Grimaud et J. Sauzier*

10 % résultent d'une forte pression commerciale qui impose l'abattage de jeunes animaux qui de surcroît sont rarement complémentés. De meilleures performances pourraient être obtenues au travers de l'installation de nouvelles structures d'exploitations.

**REMERCIEMENTS**

Les auteurs remercient l'Etablissement Départemental de l'Elevage de la Réunion, et plus particulièrement Xavier Rérolle, de leur avoir communiqué les résultats d'abattage des cerfs rusa à la Réunion.

**BIBLIOGRAPHIE**


REPRODUCTIVE PERFORMANCE OF SMALLHOLDER DAIRY CATTLE UNDER ARTIFICIAL INSEMINATION IN MAURITIUS

RK Ramnauth, P Toolsee, G Saraye, R Fakim and AA Boodoo

Agricultural Research and Extension Unit

ABSTRACT

A study was carried out to evaluate the reproductive performance of smallholder dairy cows under artificial insemination. A total of 421 cows from 388 farms located in 4 different regions were included in the study. Milk samples were taken for progesterone radioimmunoassay at the time of insemination (day 0), 10 – 12 and 22 – 24 days after artificial insemination. Data for semen and cow inseminated, including physical signs of oestrus, were recorded in a customised database application. Data generated from cows with first services were analysed. The mean calving to first service interval was 132.4 ± 63.2 days and the mean calving to conception interval was 154.9 ± 79.7 days. The mean intervals between 1st and 2nd service and between 2nd and 3rd service were 57.6 ± 39.9 and 63.2 ± 48.5 days respectively. The first service conception rate was 52.6% and was significantly influenced by the bull and semen origin (local/imported). Progesterone measurement in milk samples taken on day 0, day 10 – 12 and day 22 – 24 showed that 72.7% cows had been inseminated when progesterone level was low. 60.4% conceived by day 24 post insemination. However, 9.6% of these probably had late embryonic mortality.

Key words: progesterone, radioimmunoassay, conception rate, embryonic mortality

INTRODUCTION

The dairy production system in Mauritius is characterized by smallholdings with 1 to 3 cows per farm. For the last five years, there has been a growing number of medium-size farmers who own up to 15 cows per farm. Most of the latter are full-time farmers who are willing to adopt new technologies. According to recent estimates (AREU Livestock Extension Service, 2001) there are about 8,700 cattle heads and 2,200 cattle farms in the country. These farms produce between four and five million litres of fresh milk per year representing 95% of the total fresh milk consumption in the country. Cowkeeping has traditionally been a part-time activity and a family business. The animals are of Bos taurus genotype. They are kept in tie-stalls and managed under zero-grazing supplemented with commercial concentrate feeds. Cows are hand-milked twice per day. Calves are allowed to suckle the dam twice a day on most farms. Heat detection is based mostly on secondary heat signs and farm records are non-existent.

Artificial insemination (AI) is routinely used to breed all dairy animals in the villages. It is also used for achieving genetic progress. The artificial insemination service is under the responsibility of the Division of Veterinary Services of the Ministry of Agriculture, Food Technology and Natural Resources. It is decentralized through four veterinary sub-centres located in the North, East, South and Centre of the island. These sub-centres are the point of contact for livestock farmers who seek veterinary assistance and AI service.

The efficiency of smallholder farmers to detect oestrus, the success rate of AI and the skills of the AI technicians have recently been questioned. In order to throw light on these issues, it was decided to carry out a comprehensive study, with systematic and detailed collection of information regarding the farming system, farm characteristics, animal performance, application of the AI technique and signs of heat expression, to enable the identification of the limiting factors affecting the reproductive performance of dairy cows.
OBJECTIVE

The aim of this study was:

(a) to evaluate the reproductive performance of smallholder dairy cattle under artificial insemination in four regions of Mauritius using progesterone radioimmunoassay (RIA) and

(b) to identify the main factors limiting reproductive efficiency.

MATERIALS AND METHODS

This study followed the protocol developed by the Joint FAO / IAEA Co-ordinated Research Project entitled “Use of RIA and related techniques to identify ways of improving artificial insemination programmes for cattle reared under tropical and sub-tropical conditions” which was implemented in 14 Asian and Latin American countries (Garcia et al, 2001).

A multi-disciplinary team comprising of Research Scientists, Extension Officers and AI Technicians carried out the study. The inseminators performed the AI upon request from farmers and also carried out pregnancy diagnosis around 90 days post insemination. Any subsequent services done after first AI and the findings of pregnancy diagnosis were recorded. The Extension Officers collected the milk samples and filled in the cow data sheet. The Research Scientists collected farm data, bull / semen type data and bio-data of AI technicians. They also carried out the assays in the laboratory to determine the progesterone value in milk samples.

Farms and Animals

The study was conducted on 388 smallholder farms in 4 regions of the island having different climatic conditions: North area (dry to sub-humid with annual rainfall < 1250 mm), East and South areas (humid with annual rainfall between 1250 - 2500 mm) and Centre area (super-humid with an annual rainfall >2500 mm.

A total of 421 cows were included in the study as and when they were inseminated for the first time after parturition. The cows were of Friesian and Creole breeds and their crosses. Most of them had parities ranging from 1 to 3 and body condition score (BCS) at AI between 2.5 and 3.5 (on a scale 1-5, where 1 is very poor and 5 is fat).

Artificial insemination

Inseminations were carried out at the request of farmers after heat detection based mostly on bellowing of the cows. Semen used was frozen in 0.25 ml straws and thawed in water at ambient temperature before use. The semen were from 15 breeding bulls of Friesian and Creole breeds and their crosses. Both imported and locally produced semen were used. Inseminations were performed by 9 technicians, all regular staff of the Government AI service with a formal training in AI ranging from 2 weeks to 2 months. The inseminators also carried out pregnancy diagnosis if the cow did not return to heat at 90 days post AI.

Data collection

Information regarding the farms involved in the study, inseminated animals, semen and sires, AI technicians and heat expression observed by farmers and AI technicians was collected. Five data capture forms were used to collect field information (i.e. farm, AI technician, semen batch, cow, insemination).

Milk sampling and analysis

Three milk samples (20 ml per sample) were collected from each inseminated cow (at day 0, day 10-12 and day 22-24 after AI). The milk samples were collected in the morning in vials containing a preservative (Sodium azide tablet) and were stored at + 4°C for 3-7 days. The samples were then centrifuged at 3000 rpm for 15 minutes and the fat layer removed with a Pasteur pipette. The skim
milk fraction was then transferred into labeled vials and stored frozen (-20°C) until assayed for progesterone level. Progesterone level was measured in defatted milk samples using the direct solid-phase self-RIA technique with $^{125}$I labeled progesterone as tracer, supplied by IAEA / FAO. All the samples and standards were run in duplicate. After adding tracer to the standards, quality control and samples, all the tubes were incubated for about 12 hours at +4°C. The tubes were then decanted and counted for 60 seconds in a multi well Gamma counter (Oakfield $^\text{TM}$) equipped with a data processing software which automatically constructed the standard curve and calculated progesterone concentration (n mol l$^{-1}$) in the samples.

**Data management and analysis**

Information relating to the farms, cows, AI technicians, semen batches, pregnancy diagnosis and progesterone values were recorded in AIDA (Artificial Insemination Database Application) (Garcia, 1999).

Data were analysed for factors affecting reproductive performance (farm location, cow breed, parity, body condition score (BCS), heat signs, AI technicians, bull codes, bull breed and origin of semen) using GAIDA (Guide for AI Data Analysis), which comprises a menu of statistical procedures using SYSTAT (Goodger et al., 2001).

**Duration**

Collection of milk samples and field data started in July 1999. The last milk samples were taken in September 2000 and field data collection was completed in October 2001.

**RESULTS**

**Reproductive performance**

*Calving to first service interval and calving to conception interval*

Table 1 shows the intervals from calving to first service (CFSI) and to conception (CCI) in the four regions under study.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Mean interval (days) from calving to</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>132.4 ± 63.2$^*$</td>
<td>154.9 ± 79.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 421</td>
<td>n = 321</td>
<td></td>
</tr>
<tr>
<td>Centre</td>
<td>128.4 ± 55.6</td>
<td>146.8 ± 71.5$^a$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 150</td>
<td>n = 116</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>145.9 ± 81.7$^b$</td>
<td>178.7 ± 95.4$^b$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 132</td>
<td>n = 101</td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>124.0 ± 41.0$^c$</td>
<td>143.6 ± 66.6$^c$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 112</td>
<td>n = 91</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>124.6 ± 67.2$^c$</td>
<td>120.1 ± 59.2$^c$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 27</td>
<td>n = 13</td>
<td></td>
</tr>
</tbody>
</table>

$^a,b$ Means with different superscripts are statistically different (P ≤ 0.05)

* Standard deviation
The average calving to first service interval was 132 days with no significant difference (P ≤ 0.05) between regions. However, there were significant differences (P ≤ 0.05) in the calving to conception interval between the East and North regions (179 and 144 days) and between the East and Centre regions (179 and 147 days). The small number of inseminations carried out in the South region did not allow meaningful comparisons.

**Interval between services**

The intervals between the first and second, and between the second and third services are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2 Intervals between services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regions</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>All</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Centre</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>East</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>North</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>South</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

* a, b Means with different superscripts are statistically different (P ≤ 0.05)

The mean intervals between the first and second service, and between the second and third service were 57 and 63 days respectively. This represents an average of at least two missed heats between services. There was a significant difference (P ≤ 0.05) in the interval 1st – 2nd service between the East and the North. The small number of records in the South did not permit meaningful comparisons.

**Conception rate to first service (CRFS)**

The conception rate to first service (CRFS) for the four different regions is shown in Table 3. The overall CRFS was 53%. The CRFS in the North was 58% and 37% in the South. Cows in the Centre and East regions had 55% and 49% conception respectively. There was no significant difference (P ≤ 0.05) in CRFS in respect of location.

<table>
<thead>
<tr>
<th>Table 3 Conception rate to first service</th>
</tr>
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<tbody>
<tr>
<td>Regions</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>All</td>
</tr>
<tr>
<td>Centre</td>
</tr>
<tr>
<td>East</td>
</tr>
<tr>
<td>North</td>
</tr>
<tr>
<td>South</td>
</tr>
</tbody>
</table>
CRFS was also analysed considering the following as variation factors:
- Cow factors including reproductive characteristics of cow (breed, parity, BCS at AI) and oestrus manifestation (heat signs, degree of vulva swelling, type of mucus discharge).
- Semen factors (bull identity, bull breed, semen source).
- Inseminator factors (AI technician, formal training).

Bull and semen source significantly influenced (P ≤ 0.05) CRFS while the other factors did not have any significant effect.

### Table 4 Effect of bull and semen origin on CRFS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. of services</th>
<th>No. of conceptions</th>
<th>Conception rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull identity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucklin</td>
<td>4</td>
<td>4</td>
<td>100.0</td>
</tr>
<tr>
<td>Pecos</td>
<td>4</td>
<td>3</td>
<td>75.0</td>
</tr>
<tr>
<td>Marcos</td>
<td>5</td>
<td>3</td>
<td>60.0</td>
</tr>
<tr>
<td>Bhim</td>
<td>13</td>
<td>10</td>
<td>76.9</td>
</tr>
<tr>
<td>Legallant</td>
<td>22</td>
<td>15</td>
<td>68.2</td>
</tr>
<tr>
<td>Fleetwood</td>
<td>28</td>
<td>16</td>
<td>57.1</td>
</tr>
<tr>
<td>Leo</td>
<td>28</td>
<td>11</td>
<td>39.3</td>
</tr>
<tr>
<td>Brandy</td>
<td>33</td>
<td>17</td>
<td>51.5</td>
</tr>
<tr>
<td>Dawson</td>
<td>40</td>
<td>26</td>
<td>65.0</td>
</tr>
<tr>
<td>Zigolo</td>
<td>51</td>
<td>35</td>
<td>68.6</td>
</tr>
<tr>
<td>Saffier</td>
<td>76</td>
<td>32</td>
<td>42.1</td>
</tr>
<tr>
<td>FSR</td>
<td>101</td>
<td>41</td>
<td>40.6</td>
</tr>
<tr>
<td>Semen origin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local AI Station</td>
<td>123</td>
<td>77</td>
<td>62.6</td>
</tr>
<tr>
<td>Imported</td>
<td>282</td>
<td>136</td>
<td>48.2</td>
</tr>
</tbody>
</table>

As shown in Table 4, semen from 12 bulls had been used for first insemination. Of these, semen from eight bulls had been used for more than 20 services per bull and their CRFS ranged from 39% to 68%. Legallant and Zigolo had the highest CRFS (68%) and Leo had the lowest CRFS (39%). Semen from the local AI station had a better performance (63%) in terms of conception rate than imported semen (48%).

**Progesterone RIA**

Using progesterone values based on three milk samples taken on days 0, 10-12 and 22-24 after AI in conjunction with clinical examination (rectal palpation), it was possible to interpret the reproductive status of the cows. The results are shown in Table 5. Progesterone values are interpreted as: High ≥ 3 n mol L⁻¹, Intermediate > 1 to < 3 n mol L⁻¹ and Low ≤ 1 n mol L⁻¹.

Progesterone measurement in samples collected on day 0 showed that 72.7% of cows had been inseminated when progesterone level was low (i.e. at the appropriate time, cow not in luteal phase). Based on three milk samples, 60.4% of animals appeared to have conceived (values were low, high and high respectively); however, 9.6% of these probably had late embryonic mortality. More than 10% of inseminations, although carried out apparently at a proper time, did not result in conception and a return to oestrus was not detected until rectal palpation at 90 days. 1.5% of cows were inseminated in anoestrus and another 1.9% of cows were inseminated while being pregnant.
Reproductive performance of smallholder dairy cattle under artificial insemination in Mauritius. RK Ramnauth et al.

Table 5 Progesterone data interpretation: Diagnosis based on three samples

<table>
<thead>
<tr>
<th>Days after AI</th>
<th>Pregnancy diagnosis (rectal)</th>
<th>Frequency</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Low High High</td>
<td>132</td>
<td>Positive, Pregnant</td>
</tr>
<tr>
<td>10 - 12</td>
<td>Low High Low</td>
<td>28</td>
<td>Negative, Non-fertilisation, early embryonic mortality, post-AI anoestrus</td>
</tr>
<tr>
<td>22 - 24</td>
<td>Low High Low</td>
<td>25</td>
<td>Negative, Late embryonic mortality (&gt;day 16), luteal cyst, persistent CL</td>
</tr>
<tr>
<td></td>
<td>High High High</td>
<td>5</td>
<td>Positive, AI on pregnant animal</td>
</tr>
<tr>
<td></td>
<td>Low Low Low</td>
<td>4</td>
<td>Negative, Unsuccessful (&amp; probably unnecessary) AI combined with subsequent unobserved heat or anoestrus</td>
</tr>
</tbody>
</table>

Total values n = 260
At least 1 sample showed an intermediate value (>1 to < 3 nmol L⁻¹) n = 63
Combination of progesterone values and pregnancy diagnosis (rectal) are out of reasonable expectation due to sampling/assay errors, management inaccuracies or cow dysfunction n = 5

DISCUSSION

Farms and animals

The total number of dairy farmers on the island was estimated to be 2,200 by the Livestock Extension Department in year 2001. This study was conducted island wide in 4 different regions and covered 388 farmers, which is a good representative sample. However, only a small number of inseminations were done in the South region and this did not permit meaningful comparisons with the other regions.

The survey covered 421 cows undergoing first AI. Most cows had parities ranging from 1 to 3 and BCS between 2.5 and 3.5. This reflects a good management practice as most of the cows were young and adequately fed.

In the present study the animals were housed in-door in tie-stalls (a housing system widespread in the smallholder sector) and there was no opportunity for them to exhibit standing heat. Thus farmers had to rely on signs such as vaginal mucous discharge and bellowing. The fact that 72.7% of cows had been inseminated when progesterone was low (i.e. at the right time, cow not in luteal phase) indicates that farmers were accurate in heat detection.

Reproductive performance

Intervals from calving to first service

The overall interval from calving to first service was 132 days. The interval was similar for the 3 regions North, Centre and South (124 to 128 days), whereas it was 146 days in the East. There was no significant difference between regions. This overall interval of 132 days is long compared to optimum periods considered to be economically desirable. In order to maximize productive life, a cow should be bred within 80 to 90 days after calving (Wattiaux, 1996). The mean interval from calving to first service is similar to that obtained in a previous study in similar conditions (Boodhoo et al, 1997). This prolonged interval is mainly due to the farmer’s traditional practice not to inseminate cows earlier than three months post calving. This, therefore, points to an important need to educate the farmer on breeding goals and the economic benefits associated with insemination earlier than 3 months. The practice of calf suckling also contributes towards a long calving to first service interval. It is known that suckling has an adverse effect on the resumption of ovarian activity (Williams, 1990).
Interval between services

The intervals between the 1st and 2nd service and between the 2nd and 3rd service were 57 and 63 days respectively. This represents on average at least two-missed heats between services. This may be attributed to the farmer’s perception that once the cow is inseminated she is believed to be pregnant, and the farmer fails to observe heat again after 21 days and thereafter.

Interval from calving to conception

The mean interval from calving to conception was 155 days. This would lead to a calving interval of around 430 days, which is much longer than the optimum interval of 365 – 395 days. The interval from calving to conception is affected by the interval from calving to first service and the inter-service interval. Since both these intervals are long the interval from calving to conception is also long.

Conception rate to first service (CRFS)

The overall conception rate to first service was 53%, which is a good result when compared to results from similar studies conducted in other countries having similar dairy production systems (Garcia et al, 2001). Statistically there was no difference between the regions.

Variations in CFRS due to bulls were observed. Among the eight bulls, each of which had been used for more than 20 services, CRFS ranged from 39% to 68%. Semen produced locally had a better CFRS (63%) than imported semen (48%). Assuming that the imported semen was of good quality at the point of origin, problems during subsequent transport, storage and/or handling could be responsible for the low CFRS. These findings emphasise the need for routine monitoring of quality at the point of receipt and during storage. The need for special attention to test each batch of semen and to monitor the fertility results regularly is further stressed.

Progesterone RIA

Measurement of progesterone in milk samples collected at three specific times in relation to AI showed that almost 73% of the cows detected in heat were inseminated when progesterone concentration in milk was low (< 1 n mol L⁻¹). This shows that the farmers were accurate in detecting heat signs.

Of the cows with low, high and high progesterone in the 3 successive samples 60.4% of the inseminated ones conceived after 24 days post service but only 50.8% were confirmed pregnant by rectal palpation. About 10% of the cows had late embryonic losses and were found non-pregnant following rectal palpation, which is normally done 90 to 120 days after insemination. 11% of cows with low, high and low progesterone in the 3 milk samples did not conceive or had early embryonic mortality. In such cases the farmer should observe carefully for the next oestrus. Insemination of non-cyclic cows (1.5%) is not a major problem.

CONCLUSION

Most of the cows in the study were of parity 1 to 3 and had a BCS between 2.5 and 3.5. This reflects good herd management. The study revealed long intervals from calving to first service and to conception. For efficiency and sustainability these intervals need to be reduced. Therefore, follow-up services to farmers need strengthening.

The overall conception rate to first service was good for a tropical country (53%). However, bull and semen origin significantly influenced CRFS. Semen from the local station had a better CRFS than imported semen. Quality control of semen, therefore, needs to be established as a regular and critical feature in the AI system.

The progesterone RIA technique was a very useful tool in the study. It showed that the farmers were highly accurate in heat detection. 11% of cows, although inseminated at the proper time, did not conceive while another 10% suffered from late embryonic mortality, and a return to oestrus was not
detected until rectal palpation. One important shortcoming of farmers was that they did not look out for heat signs for about 3 months after AI, believing that the cow was pregnant once it was inseminated.

Future efforts need to be focused on stronger farmer support services and rigorous quality control in the AI system.

ACKNOWLEDGEMENTS

We thank the FAO/IAEA for their technical support and funding for the study. We are grateful to the cowkeepers in the four regions for participating in the study and for having provided the relevant samples, data and information.

REFERENCES


CHARACTERISTICS OF FAMILY POULTRY PRODUCTION IN RODRIGUES

VS Jugessur, MM Seenevassen Pillay and MJ Allas

Agricultural Research and Extension Unit

ABSTRACT

Family poultry production which is the traditional rearing of the so-called 'local' chickens in Mauritius, contributes insignificantly to the island’s total poultry meat and egg production. On the other hand, this system of production is important in Rodrigues, where almost every household owns these 'local' chickens. Exotic breeds that are imported from Mauritius are also reared for commercial purposes.

Following a survey that was carried out on selected farms with family chickens in Rodrigues in 1999 and 2000 and which provided base-line information on the health and management of family poultry production, a study was undertaken on the same farms in 2001, in order to assess the productive and reproductive performance of the birds and on the utilization of farm produce.

Results of the study showed that on an average a hen had 4 clutches per year, and 13 eggs per clutch. Hatchability was 80% and the survival rate of chicks at six weeks of age was 45%. 20% of the farmers registered financial losses. The results also provided a basis for proposing future interventions for improving family poultry production in Rodrigues.

Key words: Poultry farming, family chickens, characteristics, survey, Rodrigues.

INTRODUCTION

The majority of the 35,000 inhabitants of Rodrigues are mainly involved in agriculture and fishing. Most of the inhabitants derive a large share of their revenue from livestock farming and fishing. Rodrigues is self-sufficient in meat and eggs and more so export livestock and chicken live to Mauritius.

Poultry production in Rodrigues consists of the rearing of the so called ‘local’ or ‘Rodriguan’ chicken as well as the commercial layers and broilers imported from Mauritius.

The ‘local’ breeds of chicken that were introduced on the islands, are presumably a mixture of Rhodes Island Red, Black Orpington, Black Australorp, Naked Neck and White Leghorn breeds. Family poultry production constitutes an important source of both food and income to many Rodriguan households who rear this so-called ‘local’ breed of semi-scavenging chickens.

Since family poultry farming has been a side activity in Rodrigues, no attempt has been made to improve productivity on the farms. Currently government provides a free veterinary service, from which farmers obtain drugs and Newcastle disease vaccine (ND V4), free of charge, by calling at the veterinary centre. Farmers have continued to rear semi-scavenging birds, as these have survived outbreaks of disease and adverse weather conditions.

An applied research programme funded by the IAEA was initiated in 1998 to promote family poultry production in Africa. Within this project a survey was carried out by the Agricultural Research and Extension Unit in the winter season of 1999 and was repeated in the summer season of 2000. Three regions of Rodrigues namely, Citronelle, St. Gabriel and Trèfles, which are located 5-10 km apart and have similar social, cultural and farming activities were involved. The survey provided base-line data on flock size and structure, husbandry practices and the main problems encountered by the farmers.

Results of the survey were published in IAEA-TECDOC-xxxx (Jugessur and Seenevassen Pillay 2002).

Based on the findings of the survey, further investigations were made to evaluate the reproductive performance, feeding practices, disease control and mortality, disposal of farm produce and the benefits derived. These would enable proposals to be made to improve family poultry production in Rodrigues.
MATERIALS AND METHODS

Monitoring of farm productivity

15 households were randomly selected from those that were surveyed earlier and were visited at a monthly interval for collection of production data for nine consecutive months, as from June 2001. Data capture forms were used to record information collected from each farm on a monthly basis. The following information was collected:

- Number of cocks, hens, growers and chicks on the farm at the end of each month
- Number of cocks, hens, growers and chicks sold, or died during the month
- Number of birds consumed or donated per month
- Disease occurrence and control measures taken
- Types and quantity of feeds used, and feed costs
- Other expenses incurred and purpose
- Revenue obtained from the sale of chickens and eggs.

Reproductive performance

Four randomly selected laying hens were monitored per farm for individual reproduction performance and the following information was collected:

- Number of eggs laid
- Number of eggs incubated
- Number of chicks hatched and date of hatching

Chicks that were hatched from the four hens were followed for a period of six weeks to determine chick survivability at the end of the six weeks.

Control of endoparasitic infestations

Since the results of the previous survey had revealed parasitic infestations (Jugessur and Seenevassen Pillay 2002), a prophylactic treatment against helminth parasites and coccidia was given at regular intervals of three months. Piperazine citrate was given at the rate of 1g l⁻¹ of drinking water to control helminth parasites. Sulphadimidine in combination with Diaveridine was given at the rate of 1g l⁻¹ of drinking water to control coccidia. The anthelmintic drug was given first followed by the anticoccidian one week later.

Examination of fecal samples

2-3 fresh fecal samples were collected from the ground on each farm before the administration of the anthelmintic, and then similarly, once every three months, for the detection of endoparasitic helminth eggs and coccidian oocysts. A total of 37 samples were collected prior to the first administration of the anthelmintic and 30 samples before the second and third administrations. Qualitative examination of the samples was carried out using the Simple flotation technique as described by Permin and Hansen (1998).

RESULTS AND DISCUSSION

Flock size and structure

The winter season and summer season surveys of 1999 and 2000 had revealed that the average number of the semi-scavenging ‘local’ chickens was 86 and 110 per farm, respectively. Besides chickens, the farmers also owned ducks, guinea fowls, turkeys, and pigeons. (Jugessur and Seenevassen Pillay 2002).

At the beginning of the investigations in June 2001, the average number of birds on the farms was 91.8 per farm. At the end of nine months, the average number of birds was 92.1 per farm (Table 1). The evolution of the flock structure throughout the nine months is illustrated in figure 1. The number of adult cocks and hens was rather stable compared to those of chicks and growers as they were kept...
for breeding purposes. The variation in the number of growers was mainly due to sale at different periods, while the number of chicks was influenced by periodic hatching and mortality throughout the year.

**Figure 1** Evolution of the Flock structure from June 2001 to February 2002

The actual ratio of adult cock to hen calculated from table 1 was 6.3 compared to an average of 3.8 for the African countries as quoted by Goodger et al 2002. Since the ratio of male to female chicks at hatching is one, this suggests that more young males were sold in preference to hens which were kept for reproduction, more so, as farmers indicated that they obtained a better price for the young cocks.

<table>
<thead>
<tr>
<th>Average number of birds</th>
<th>Cocks</th>
<th>Hens</th>
<th>Growers</th>
<th>Chicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2001</td>
<td>3.21</td>
<td>18.5</td>
<td>28.1</td>
<td>41.9</td>
</tr>
<tr>
<td>February 2002</td>
<td>3.14</td>
<td>21.8</td>
<td>39.1</td>
<td>28.1</td>
</tr>
<tr>
<td>Dead</td>
<td>0.80</td>
<td>2.3</td>
<td>5.2</td>
<td>117.0</td>
</tr>
<tr>
<td>Sold</td>
<td>0.30</td>
<td>6.0</td>
<td>26.7</td>
<td>0</td>
</tr>
<tr>
<td>Consumed</td>
<td>2.10</td>
<td>28.0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 1** Flock status 2001-2002

Reproductive performance

Monitoring of reproductive performance revealed that a hen had on an average 4 clutches per year compared to an average of 3 for the African countries (Goodger et al 2002). The average number of eggs laid and incubated per hen was 13. (Table 2).

Eggs from more than one hen were often mixed for incubation. The relatively high hatchability (80%) was an indication of good fertility and brooding of the birds. In fact, farmers were aware of the prerequisite for good hatching and avoided setting their eggs in winter. They also believed that incubated eggs get spoilt during thunder storms.
Table 2 Reproductive performance of the Rodriguan ‘local chicken’

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Average ± sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of clutches / hen / year</td>
<td>4</td>
</tr>
<tr>
<td>Number of eggs laid</td>
<td>13 ± 2.2</td>
</tr>
<tr>
<td>Number of eggs incubated</td>
<td>13 ± 3.2</td>
</tr>
<tr>
<td>Number of eggs hatched</td>
<td>10 ± 3.7</td>
</tr>
<tr>
<td>Hatchability</td>
<td>80% ± 10</td>
</tr>
</tbody>
</table>

Housing

75% of the farmers provided some sort of shelter to the birds, mainly to the chicks, in the form of artisanal poultry cages made of wood and wire-netting, or baskets, tins, and boxes. Otherwise, most of the adult birds perched on trees at night. The fact that the birds were not properly housed could be one of the factors that contributed to mortality and low survivability in chicks, as they were exposed to harsh environment conditions and predators. Moreover, absence of appropriate housing encouraged the hen to lay in unprotected places with the result that very often the eggs were either eaten by predators or were lost or got spoilt.

Feeding

Birds were allowed to scavenge on all the farms. While scavenging, the birds consumed mainly grass, insects, and worms, which were moderately available throughout the year. In addition, supplements like concentrate, rice, bread and maize were also given to the birds. The percentage of farms giving these different types of feeds as well as the proportion of the different feed types in the feed cost are recorded in Table 3.

Table 3 Feeding practices and contribution of different feed types in the feed cost

<table>
<thead>
<tr>
<th>Feed type</th>
<th>% farms</th>
<th>% contribution to feed cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate</td>
<td>100</td>
<td>62.4</td>
</tr>
<tr>
<td>Rice</td>
<td>93</td>
<td>24.2</td>
</tr>
<tr>
<td>Bread</td>
<td>27</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Feeding of concentrates to scavenging chicken provided for the essential nutrients not found while scavenging and represented an average of 62.4% in the feed cost as they were relatively costly compared to the other supplements. In fact, concentrates are meant for improved breeds of chicken which are confined permanently.

Disposal of chickens and eggs produced

Part of the chickens and eggs produced were utilized for home consumption and donations on almost all the farms. 80% and 46% of the farms sold chickens and eggs respectively, for deriving additional income. These were generally sold to tradesmen, consumers, and itinerant salesmen on 83%, 75% and 42% of the farms, respectively (Jugessur and Seenevassen Pillay 2002).

From the production, 65% and 46% of the chickens and egg were sold (Figure 2). The average unit price of live chicken was R. 95 ranging from R 38 to R 142 and the average unit price of egg was R. 2.86 ranging from R 2.10 to R 3.00.

Export to Mauritius

Export of ‘local’ chicken live from Rodrigues to Mauritius was done by ship once or twice every month. The birds were bought mainly by the Chinese community who consider these very tasty,
hence ensuring a guaranteed market for the product. The evolution of the number of birds exported on a yearly basis for the last ten years has shown a constant trend as illustrated by figure 3, with an average of 26,100 birds of a value of around R 2.5 M. (Anon 2002)

**Figure 2** Proportion of chicken and egg sold and consumed

**Figure 3** Export of ‘local’ Rodriguan chicken live to Mauritius (1991 – 2001)
Economic Returns

The only expenses incurred on all the farms were the money spent on feeds. The benefits derived from the family poultry production was therefore calculated by subtracting the expenses on feeds from the total income. Total income was the sum of the revenue from sale of chicken and eggs and the value of the chicken and eggs consumed or donated taken at the current cost. The benefits thus obtained were extrapolated on a yearly basis and it was found that 20% of the farms were experiencing losses from R 1,830 to R 8,480. The benefits obtained by the remaining 80% varied according to the flock size that is from 923 to 26,226 per year. When expressed on a unit basis where the benefit was divided by the number of birds at the beginning of the study, it was found that they varied from R 26 to R 181 with an average of R 84 per year.

Diseases and disease control

Birds on all the farms that were under study were vaccinated against Newcastle Disease and Fowl Pox by the farmers. No disease outbreak was reported during the investigation. Disease problems were reported on all the farms that were surveyed in 1999 and 2000 and mortality in chicks was of the order of 50%. In the investigation, the average mortality per farm per month over the period of 9 months, was found to be 39% ± 18%, and was mostly in chicks. Most of the farmers managed to treat their adult sick birds by resorting mainly to traditional methods as was revealed in the survey (Table 4).

Table 4 Treatments given to control disease

<table>
<thead>
<tr>
<th>Disease / Symptom</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fowl pox</td>
<td>Vaccine, lemon juice, tomato seeds, kerosene</td>
</tr>
<tr>
<td>Lice</td>
<td>Wild tobacco leaves, insecticides</td>
</tr>
<tr>
<td>Fever</td>
<td>none</td>
</tr>
<tr>
<td>Drooping neck</td>
<td>none</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>none</td>
</tr>
<tr>
<td>Twisted neck</td>
<td>Vaccination, garlic with kitchen oil, sea water</td>
</tr>
<tr>
<td>Newcastle Disease</td>
<td>Vaccination, sea water</td>
</tr>
</tbody>
</table>

Survivability of chicks

The chicks that were hatched during the study were monitored for six weeks because it is the period when they are most vulnerable and very susceptible to diseases and predators. Chick survivability over a period of six weeks has revealed that 44.6% ± 27% of chicks survived up to the age of six weeks. (figure 4). The chicks were not confined on most of the farms but were allowed to roam with the hen. They were thus exposed to environmental hazards including predators.

Parasitic infestations

Fecal examination revealed a low infestation rate (+) with parasitic helminth the ova of Ascaridia spp. and with coccidian oocysts of Eimeria spp. on 20% of farms, before the administration of the anthelmintic and the anticoccidian. No helminth the ova or coccidian oocysts was detected after the first and second application of the respective drugs. There was thus, an effective control of helminthie and coccidian parasites.
CONCLUSION

The major problems revealed by the study were poor housing, relatively high expenses on feeds, high mortality and low chick survivability.

Since ‘local’ chicken are semi scavenging birds they should not be confined permanently. However, provision of low cost housing should be made to protect them from natural calamities. Chicks should be confined until they are strong enough to withstand attack from predators and unfavourable environmental conditions.

The farmers should limit the feeding of concentrates only to laying hens and chicks to reduce expenses on feeds; cheap supplements such as rice, maize and vegetables should be fed instead.

Endoparasitic infestations were not of major importance, as the birds controlled these naturally. However, a systematic prophylactic treatment against parasitic helminthes and coccidia would reduce further, the risks of re-infections.

The fact that no major disease outbreak, especially Fowl Pox and Newcastle Disease were reported on the farms that participated in the study, implies that vaccination of all family poultry against these two diseases should be maintained.

The constant trend in the export on ‘local’ chickens from Rodrigues to Mauritius clearly indicates that family poultry production will continue in years to come as there is a guaranteed market for such produce in Mauritius. Although attempts are being made to promote production of chicken of the improved breeds in Rodrigues, ‘local’ chickens production will continue to maintain itself because of its specificity in terms of low investment and taste. In fact, the study has shown that the only investments were on feeds and low cost housing. It is also known that ‘local’ chicken from Rodrigues are appreciated because of their taste. The quest for a different taste of chicken considered to be produced under ‘natural’ conditions will contribute to make family chicken production a more lucrative business.
ACKNOWLEDGMENTS


REFERENCES


ACCURACY AND ECONOMIC EVALUATION OF NON-PREGNANCY DIAGNOSIS IN DAIRY CATTLE IN MAURITIUS
BY MILK PROGESTERONE DETERMINATION

Parmessur Toolsee
Agricultural Research and Extension Unit

ABSTRACT

The milk radioimmunoassay technique, based on measuring progesterone concentration in milk samples, allows to identify cows that are not pregnant as early as day 24 post insemination. Milk samples collected on day of insemination, 10-12 and 22-24 days after insemination were used to diagnose the pregnancy status of cows based on the progesterone concentration in milk samples. Accuracy of non-pregnancy diagnosis was 96 and 98 % for samples collected from on-farm and Curepipe Livestock Research Station. The decision to use the radioimmunoassay for early detection of non-pregnant cows was evaluated by use of the decision analysis method. A decision tree was formulated and used to compare the radioimmunoassay method with the alternative of rectal palpation alone for determination of pregnancy. The expected cost to identify non-pregnant cows using the radioimmunoassay was Rs903 against Rs3710 for rectal palpation. Use of radioimmunoassay for early detection of non-pregnant cows appears to be economically advantageous and it reduces the cost associated with reproductive inefficiency.

Keywords: radioimmunoassay, oestrus, decision tree, days open.

INTRODUCTION

Reproductive efficiency in dairy cattle is directly affected by calving interval which includes the time between breeding and conception. The ability to reduce the number of days a cow is not pregnant and which accumulates during the interval from calving to conception is limited, because the pregnancy status of the bred cows cannot be confirmed through rectal palpation until 90 days post breeding or until the cow is observed to be on heat again. Cows that do not conceive and are not identified on heat on day 21 post insemination, accumulate the number of days they are open (not pregnant) which is the interval between calving and conception. Thus, early identification of non-pregnant cows is essential to minimise the number of days that they remain open.

Heap et al (1973) were the first to suggest a milk progesterone test for diagnosis of pregnancy and infertility. Pregnancy status can be determined on days 22-24 after breeding by assay of the steroid hormone progesterone. Progesterone is produced and released into the blood and milk by the corpus luteum. Progesterone is present at varying levels during the reproductive cycle and pregnancy, and is commonly referred to as the hormone of pregnancy. The level of progesterone is low (< 1 nmol/l) during oestrus and begins to rise after ovulation as the corpus luteum develops. When a cow is not inseminated or fails to conceive following breeding, the corpus luteum begins to degenerate (due to prostaglandin release from the uterus) on approximately day 17 of the cycle. Furthermore, progesterone level declines to minimal concentration (<1 nmol/l) on days 21 through 24 as the cow returns to oestrus. On the other hand, when a cow is inseminated and conceives, the corpus luteum is maintained. The cow does not return to oestrus and progesterone concentration in blood and milk remains elevated during pregnancy (>3.5 nmol/l) until just prior to calving. The concentration of progesterone in blood is highly correlated ($r^2=0.8$) with the concentration in milk (Kanboj et al, 1993). Thus analysing cows’ milk provides an accurate measurement of the level of circulating progesterone. Collecting milk samples is non-invasive, easy and practical compared to taking blood samples. Accurate determination of which cows are pregnant and, more importantly, which cows are not pregnant is an essential part of good reproductive management. The non-pregnancy test based on measuring milk progesterone values allows the identification of cows that are not pregnant as early as 24 days post insemination. Reducing the interval from calving to conception, by identifying the non-
pregnant cows as early as 24 days post insemination, will help to reduce the calving interval. Dairy cattle calving at 12-13 months interval have a better reproductive performance in terms of the number of calves produced per cow and total milk production during their lifetime (Esselmont, 1992). Historically, pregnancy in cattle has been determined by palpation via rectum. The main disadvantage of this method is that it requires a longer waiting period (about 90 days in our local context) after insemination. However, the milk progesterone test provides the opportunity to determine the status of bred cows 24 days post insemination.

**OBJECTIVE**

This study was undertaken to determine (a) the accuracy of pregnancy diagnosis based on progesterone values in milk on days 22-24 post insemination and (b) the cost of using the radio-immunoassay milk progesterone test for early detection of non-pregnant cows for decision making.

**MATERIALS AND METHODS**

**Dairy system and location**

Our dairy system is characterized mainly by small farms having 1 to 3 cows per farm and by being a part time activity as well as a family business. There are also a few emerging medium farms with 4 or more cows per farm. They are full time dairy farmers who are more likely to adopt new technology. Artificial insemination (AI) is routinely used to breed all dairy cows. The AI service is under the responsibility of the Division of Veterinary Services of the Ministry of Agriculture, Food Technology and Natural Resources. This field study was done on small and medium farms in four different regions of the island namely Centre, East, North and South. Collection of milk samples and data started in July 1999 and ended in August 2000, with a target to monitor a total of 500 first inseminations. Farmers were contacted through the veterinary sub-centres. The inseminators did insemination upon request from farmers and also rectal pregnancy diagnosis if the cow did not return on heat 90 days after insemination. Cows kept at Curepipe Livestock Research Station (CLRS) of the Agricultural Research and Extension Unit (AREU) were also monitored.

**Milk sampling and progesterone analysis**

To assess pregnancy status, three milk samples (20 ml per sample) per cow were collected from cows undergoing AI. The first sample was taken on the day of insemination, the second between 10-12 days and the last sample between 22-24 days after AI. Samples collected on days 22 to 24 after insemination are critical for an accurate pregnancy diagnosis. It is only at this time that the milk progesterone test can distinguish between pregnant and non-pregnant cows based on the progesterone concentration. The milk samples were collected in vials containing a tablet of preservative (sodium azide) and were then kept at +4°C for 3-7 days after field collection. They were then centrifuged at 3000 rpm for 15 minutes and the fat layer removed with Pasteur pipettes. The skim milk fraction was then transferred into another properly labelled vial and stored frozen (-20°C) until assayed for progesterone concentration.

The technique used to determine the progesterone concentration in defatted milk samples in the laboratory was the solid phase radioimmunoassay (RIA) using $^{125}$I progesterone as labelled tracer (Plaizier, 1993). The performance of our RIA laboratory was monitored through an External Quality Control Service organised twice yearly by the agricultural laboratory of International Atomic Energy Agency/ Food and Agriculture Organisation (IAEA/FAO). The intra and inter assay coefficients of variation were 3.5% and 9.2% respectively. The sensitivity (detection limit) of the assay is 0.1 nmol/l.
RESULTS AND DISCUSSION

The results of the accuracy of pregnancy diagnosis using the radioimmunoassay are shown in Table 1.

Table 1  Accuracy of pregnancy diagnosis based on milk progesterone and confirmed by rectal palpation on day 90 post AI

<table>
<thead>
<tr>
<th>Number of cows</th>
<th>Non-pregnancy</th>
<th>Pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On farm CLRS</td>
<td>On farm CLRS</td>
</tr>
<tr>
<td>diagnosed by milk progesterone</td>
<td>54 80</td>
<td>201 47</td>
</tr>
<tr>
<td>confirmed by rectal palpation</td>
<td>52 78</td>
<td>170 39</td>
</tr>
<tr>
<td>Accuracy (%)</td>
<td>96.3 97.5</td>
<td>84.6 83</td>
</tr>
</tbody>
</table>

Sets of three milk samples from 255 and 127 cows collected from on-farm and CLRS respectively gave sufficient data for meaningful statistical analysis. 54 and 80 cows from on-farm and CLRS respectively were diagnosed not pregnant with the progesterone test on day 24 post-insemination. Rectal palpation done around 90 days post insemination to confirm pregnancy status revealed that 52 and 78 of them were in fact not pregnant. The accuracy of detecting non-pregnant cows with the milk progesterone assay in this study was therefore 96.3 and 97.5% for on-farm and CLRS respectively. The accuracy of positive pregnancy diagnosis was 85 and 83% for samples collected from on-farm and CLRS respectively. The high value of progesterone concentration on days 22 to 24 indicates that the cow has 0.83 to 0.85 probability of correctly being confirmed pregnant by radioimmunoassay. These results are in agreement with other studies using the radioimmunoassay technique (Nebel et al, 1987; Ruiz et al, 1989 and Kaul and Prakash, 1994).

The cows that were diagnosed non-pregnant (15-17 %) by rectal palpation had in fact been found to be pregnant by the progesterone assay on day 24 post insemination. The accuracy of estimating pregnancy by milk progesterone is affected by numerous factors. They can occur in the length of oestrus cycle, presence of a persistent corpus luteum, insemination during the luteal phase and embryonic death. A non-pregnant cow can show oestrus less than 21 days after insemination. This cow may ovulate and form a corpus luteum, which leads to an increase in progesterone concentration through days 22 to 24. Thus, this non-pregnant cow may be wrongly diagnosed as pregnant by progesterone assay. Cows with reproductive problems such as ovarian cysts or uterine infections may also have two consecutive high progesterone concentrations (>3.5 nmol/l) and be diagnosed as pregnant. Sometimes cows are inseminated when not really in oestrus (>1.5 and <3.5 nmol/l). At 21 days after insemination, these cows are often in the luteal phase and have high progesterone concentrations (>3.5 nmol/l) even if not pregnant. Moreover, cows may be pregnant at 21 days after insemination but lose the embryo in the next 30 to 60 days. Pregnancy losses in this period may reach up to 30 % (Gordon, 1996). It was not possible in this study to quantify which were the factors responsible for the cows to be declared non-pregnant on day 90 post-insemination although they had been diagnosed to be positively pregnant by milk progesterone assay.

Measuring progesterone concentration on days 0, 10-12 and 22-24 after AI has permitted an accurate assessment of the reproductive status of inseminated cows. The accuracy of the milk progesterone radioimmunoassay technique for positive pregnancy diagnosis was from 83 to 85% whereas for non-pregnancy diagnosis it was almost 98%. Previous work (Boodhoo et al, 1997) has shown that the efficiency of oestrus detection is low (around 31%) particularly after insemination. With the milk progesterone test, cows which have not conceived after AI can be identified at an early stage and the farmer can be called upon to detect next heat signs and to breed the cows. Therefore, this test also helps to increase the efficiency of oestrus detection.

Cost of progesterone determination for one cow

The cost to determine the progesterone values on a set of 3 milk samples collected from a cow is Rs129. The cost of the labelled tracer is based on subsidised price by IAEA/FAO. Appendix I shows the cost structure of the self radioimmunoassay technique.
Economic evaluation of the milk progesterone assay

The objective is to find out whether or not to use the milk progesterone assay for early detection of pregnancy state. The reproductive status of each cow is followed up to 90 days after insemination. A decision tree was used to represent alternative strategies for detection of pregnancy status using the radioimmunoassay (RIA) together with rectal palpation.

The decision tree (Figure 1) shows the various pathways and outcomes that are possible to determine the pregnancy status of the cow. After a cow has been inseminated, the pregnancy status can be determined by the radio-immunoassay or through rectal palpation. Certain assumptions have been used in the decision tree. The first one, the conception rate in cows identified in oestrus solely by use of milk progesterone assay is 49% (Toolsee et al, 2002). This is not significantly different from that of cows inseminated at observed oestrus, which is 52% (Division of Veterinary Services, 2002). Thus, it is estimated that the prevalence of conception rate is 50%. The second assumption is that milk samples for progesterone assay are taken at the proper time (day of insemination, 10-12 and 22-24 days after insemination).

Figure 1 Decision Tree

The RIA result shows high progesterone value on day 24, indicating that the cow may be pregnant. However, rectal palpation shows that the cow is not pregnant; she accumulates 66 open days (90-24) (a). On the other hand, when RIA result shows high progesterone value on day 24 and the cow is truly pregnant she does not accumulate any open days (b). Low progesterone value on day 24 shows the cow is not pregnant and she might be re-bred on next heat (c). A low progesterone value calculated from the RIA on day 24 shows non-pregnancy but in reality the cow is pregnant (d). The other possible pathway is that the cow does not undergo the RIA test, the result of pregnancy is known at day 90 days post insemination by rectal palpation. In this case, if the cow is pregnant, she does not accumulate any open days (e). In case of non-pregnancy, the cow remains open for 90 days (f).

When the RIA is used, the probabilities considered are the prevalence of the value of conception rate and the value of the test corresponding to each branch extending from day 24. In case the decision is to use rectal palpation alone, the probability used is the prevalence of the value of conception rate. The
outcome cost is S cost of the test + cost of AI + {number of days a cow is open * its cost}. The expected cost is when the outcome costs are multiplied by their respective probabilities and rolled back to the initial decision node in the decision tree. The optimum decision is that resulting in the lowest expected cost. Since all cows are palpated per rectum to confirm pregnancy status, the cost of rectal examination has not been included. The costs incurred when a cow is open are mainly from milk not produced per day and loss of calf. The calculation for the costs incurred when a cow is open is shown in Appendix II.

When a cow is diagnosed not pregnant by day 24, the cow remains open for 21 days until re-inseminated on next heat and the expected cost is Rs903 (Figure 1). In case a cow does not go through the RIA and diagnosed not pregnant by rectal palpation, the expected cost for 90 days open is Rs3710. The RIA shows a high degree of accuracy (98%) to predict non-pregnant cows as early as on day 24 post insemination and a low value of expected cost is obtained (Rs903) compared to use of rectal palpation only (Rs3710).

A cow which is diagnosed pregnant by RIA on day 24 post insemination but later found to be non pregnant on day 90 by rectal palpation, remains open for 66 days. In this case the expected cost is Rs445.

For cows found pregnant on day 90 and confirmed to be pregnant by RIA, the expected cost is around Rs55. The RIA is therefore more useful and economical to detect the non-pregnant cow as early as 24 days post insemination.

A service for dairy farmers based on the RIA technique is being implemented on a pilot basis in Morocco in collaboration with IAEA/FAO (Galloway et al 2001). In Mauritius, the RIA technique has the potential for non-pregnancy diagnosis. In this test a waiting period of around 7-10 days after last milk collection is important for progesterone analysis and feedback of results to the farmers for decision-making. It is also important that farmers are educated in the significance of positive and negative result and the managerial activities that should follow under each possibility. The collaboration of the Division of Veterinary Services is essential. The RIA technique can help to improve the productive and reproductive status of cows.

**CONCLUSION**

This study has been an important first step in experimental work on non-pregnancy diagnosis using the RIA technique. The use of RIA to quantify progesterone levels in milk samples and to monitor early non-pregnancy in dairy cows is highly accurate (98%) and it is a useful technique. The expected cost for early non-pregnancy diagnosis using RIA is low (Rs903) compared to use of rectal palpation only (Rs3710). Using the milk progesterone test in cows that are non-pregnant and undetected (visually) in oestrus 21 days post breeding has the potential to improve the reproductive efficiency. This will lead to a reduction in calving interval and increased income to the farmer.

**ACKNOWLEDGEMENTS**

I wish to thank the IAEA / FAO for their technical support and funding for the study. We are grateful to the smallholder farmers for having provided the relevant milk samples, data and information. We are also very grateful to the following persons for having provided their support during the study: the Principal Research Scientist, AA. Boodoo for proper guidance and support, the Biometrician, R. K Rammouth for data analysis, Extension Officers for collection of milk samples, the Division of Veterinary Services for access to records.
REFERENCES


Appendix I Cost structure of self radioimmunoassay

Assumption:
The cost of the gamma counter and computer is not included
A minimum of 150 tubes is required to run one assay, out of which 16 tubes are for the standards

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Man days required</th>
<th>Amount (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Assistant Research Scientist</td>
<td>1</td>
<td>455</td>
</tr>
<tr>
<td>1 Laboratory attendant</td>
<td>1</td>
<td>273</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumables</th>
<th>Unit</th>
<th>Amount (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium azide</td>
<td>130 vials, 2 sticks per vial</td>
<td>130</td>
</tr>
<tr>
<td>Vial (25 ml to collect milk)</td>
<td>130 vials</td>
<td>260</td>
</tr>
<tr>
<td>RIA tracer</td>
<td>1 assay</td>
<td>1667</td>
</tr>
<tr>
<td>150 star tubes</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Misc. (electricity, stationery...)</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3234</td>
</tr>
<tr>
<td>for 150 tubes  it cost</td>
<td></td>
<td>3234</td>
</tr>
<tr>
<td>for 3 tubes ( in duplicate), it costs</td>
<td></td>
<td>129</td>
</tr>
</tbody>
</table>

Cost of progesterone determination (set of 3 milk samples) for 1 cow  129

Appendix II. Cost incurred when cow is not pregnant

It is assumed that a cow produces an average of 8 litres of milk per day and selling price is Rs9 per litre. On a monthly basis, revenue from milk foregone is Rs2160.
For loss of calf, calculations are done with the following assumptions. The first calving for a heifer is at the age of 30 months, an ideal calving interval of 12 months and productive lifetime of 78 months. From these assumptions, 5 calves are obtained during the production period before the cow is culled. The estimated weaning weight of a calf at 3 months of age is 80 kg and selling price is Rs 60 kg live-weight, thus the calf is valued at Rs 4800. The monetary value of a new born calf is Rs 3756 (excluding feed and management cost estimated at Rs 1044). The cow produces a calf every twelve months. Thus the monthly revenue foregone for calf is Rs 313. The estimated monthly loss of revenue for an unproductive cow is Rs 2473 (2160 + 313).
ANALYSIS AND APPRAISAL OF A DAIRY CATTLE RESEARCH FARM IN A DEVELOPING COUNTRY: MAURITIUS

G Prayagsing and R Ramchurn

Faculty of Agriculture University of Mauritius

ABSTRACT

A study was carried out to assess the management operations, efficiency and constraints to research work at Curepipe Livestock Research Station (CLRS). The work consisted of on site visits, interviews and collection of specific data in a questionnaire. The results showed that 90% of the manual workers were young (below 40 years old). Feeds were provided according to the growth stages of the animals. Disease occurrence was low for most of the disease except for diarrhoea (40%) and worms (24%). The conception rate with artificial insemination had increased significantly over the past two years from approximately 28% to about 50%. The mortality rate was satisfactorily around 6%. The calving interval was short (13 – 14 months) and the average daily gain in weight of young animals in year 2000 was maintained at about 550 gd⁻¹. The major constraint to research work was the high rate of absenteeism among manual workers (12%). The cost analysis showed that feeds and fodder (47%) and wages (36%) were the highest monetary inputs. It was concluded that the station was operating at a satisfactory management level, however, improvement in infrastructures and attention to constraints such as, high rate of absenteeism and high cost of research were required.

Keywords: labour, feeding, experimentation, health care, marketing, efficiency, constraints and costs

INTRODUCTION

Agricultural research is normally intended to maximise the use of natural resources to generate private and public benefits. As such, it can be considered as a form of economic investment, where experiments in agriculture are carried out with the expectation that these would bring returns in the future (Tabor, Jansen & Hilanaon, 1998). Tabor et al. (1998) indicated that in 1991 the total agricultural research expenditure for Mauritius was US $ 5 million and the share of the Gross Domestic Product (GDP) allocated to agricultural research was 0.2 %. They noted that this share was even higher than in some Asian and African countries.

Research in Mauritius is carried out by the public sector, which comprises of the Government dairies on one side and Research Stations such as the Mauritius Sugar Industry and Research Institute on the other side. The Research Station is usually a non-profit making unit. One such unit involved in livestock research in Mauritius is the Curepipe Livestock Research Station (CLRS).

The CLRS is engaged intensively in feeding trials as well as in other livestock related experimentation. This station has undergone substantial changes since January 1999, when it was taken over by the Agricultural Research and Extension Unit (AREU). AREU invested to renovate the station, but, inspite of the work carried out since 1999, there was still much work to be done.

It was noted that despite being a major research centre, only scientific papers confined to nutrition and reproduction aspects of livestock had been published. No exercise or assessment on the management practices pertaining to the station had been carried out in the past. So, the objectives were:

1. To investigate the farm efficiency measures
2. To identify outcomes of experiments and the constraints to research work
3. To analyse the cost involved in dairy research
4. To propose some scenarios regarding improvement at the station
METHODOLOGY

The methods used for the completion of the project were based on surveys, on site visits, interviews and specific data collection. A questionnaire was prepared. Prior to designing the questionnaire, background information on cattle and cattle management was gathered from textbooks, papers, journals, and the Internet. A final structured questionnaire was then designed taking into consideration the objectives of the study. A survey was performed in the form of visits and personal interviews. On site visits were made to take some measurements of infrastructures and to carry out visual assessment of the animals, buildings, husbandry practices as well as the farm environment. Personal interviews were in both Creole and English language depending on the person interviewed. The respondents were the staff members, researchers and manual workers.

RESULTS

Farm structure

The total area of the farm was about 8 hectares where 2.5 hectares was occupied by fodder and the rest by buildings and yard. Pastures at the station could not be differentiated into specific plant species since they were grown as mixed fodder. About 1.8 hectares was unattended while 0.7 hectares were looked after with care and harvested 3 – 4 times per year.

Labour force

Category of workers and age groups

Table 1 show that the largest category of workers was manual and was below 40 years old while there was an equal partition among the researchers at the station i.e. 50%.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Percentage (%) of workers in different age groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 40 years</td>
</tr>
<tr>
<td>Administrative</td>
<td>5 (2 females)</td>
<td>60</td>
</tr>
<tr>
<td>Researchers</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Manual workers</td>
<td>22 (2 females)</td>
<td>90</td>
</tr>
</tbody>
</table>

It was found that 60% of workers were satisfied with their work as well as the work allocation.

Cost of labour on station

Analysis had shown that the costs (Rs) per man per day of the workers were as follows:

1. Administrative workers: Rs 463 / day
2. Research workers: Rs 694 / day
3. Manual workers: Rs 183 / day

Absenteeism

Table 2 shows that there was a high rate of absenteeism among the manual workers. For SRS / RS / ARS, the rate was high due to the nature of their work (field). The rate of absenteeism among the manual workers was highest on Mondays (26%) and Tuesdays (19%).
Table 2 Percentage (%) absenteeism of workers from July to December 2001

<table>
<thead>
<tr>
<th></th>
<th>Manual workers</th>
<th>Administrative workers</th>
<th>SRA / RA</th>
<th>SRS / RS / ARS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stockman GFOPW</td>
<td>Staff</td>
<td></td>
<td>On farm</td>
</tr>
<tr>
<td></td>
<td>11.7</td>
<td>5.9</td>
<td>3.3</td>
<td>19.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.9</td>
</tr>
</tbody>
</table>

Farm animals

It was found that the number of Friesian breed was highest (46%) followed by Cross (34%), Creole (19%) and Jersey (1%). Also, being a dairy farm cows were the largest category of animals kept, followed by heifers and weaners. The ratio of reproductive male to female was 1:12

Nutrition

Water requirements and feeding standards

Tap water was provided ad libitum through automatic and bucket drinkers. With the automatic drinkers, there was no control since it was connected to a constant water supply. On the other hand, the bucket drinkers were filled twice per day especially in the morning and at midday. Fodder (5 tons) constituted the highest daily feed since it consist the bulk of animal feeds. A large amount of cowfeed (554 kg) was used compared to other concentrates such as cotton seed cake (CSC), bull feed and calf feed.

Feed requirements of different animals

Table 3 shows the feeding ration for milch cattle at the station during various growth stages. Dry cows, which were not pregnant, were provided with basic requirement for maintenance. When they were pregnant, the amount of cowfeed was increased. As for the lactating cows, besides the basic needs, they were provided with urea/molasses mixture, milk and the amount of mineral mixture were also increased.

Table 3 Feed requirements of milch cattle during different growth stages

<table>
<thead>
<tr>
<th></th>
<th>Chipped Sugarcane tops (kg)</th>
<th>Cow feed (kg)</th>
<th>Urea / Molasses (kg)</th>
<th>Mineral mix (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactating</td>
<td>45</td>
<td>2.0 + (0.5 litres of milk)</td>
<td>3.0</td>
<td>60</td>
</tr>
<tr>
<td>Dry &amp; non-pregnant</td>
<td>45</td>
<td>2.0</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Dry &amp; pregnant</td>
<td>45</td>
<td>3.0</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Last 2 months of gestation</td>
<td>45</td>
<td>3.0 - 5.0 (Dep on BCS)</td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

Tables 4 and 5 show that for growing animals (bulls and heifers), as the liveweight (LWT) increases the amount of sugar cane tops / fodder was increased. The amount of cowfeed was also slightly increased. Pregnant heifers were provided with the same ration as at 400 kg LWT. Breeding bulls were given 55 kg of fodder, 5 kg of Bullfeed and 0.25g of mineral mixture.
Table 4 Feed recommendation for growing and breeding bulls

<table>
<thead>
<tr>
<th>Growing bulls weight kg</th>
<th>Breeding bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Fodder kg</td>
<td>10</td>
</tr>
<tr>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Cowfeed</td>
<td>2</td>
</tr>
<tr>
<td>Bullfeed</td>
<td></td>
</tr>
<tr>
<td>Mineral Mix g</td>
<td>25</td>
</tr>
<tr>
<td>Urea / Molasses</td>
<td>1</td>
</tr>
<tr>
<td>CSC kg</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 5 Feed recommendation for growing and pregnant heifers

<table>
<thead>
<tr>
<th>Growing / Pregnant Heifers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights 100 150 200 250 300 350 400</td>
</tr>
<tr>
<td>Fodder kg</td>
</tr>
<tr>
<td>Cowfeed</td>
</tr>
<tr>
<td>Mineral Mix g</td>
</tr>
</tbody>
</table>

Table 6 Feed recommendation for calves

<table>
<thead>
<tr>
<th>Period</th>
<th>Milk (L)</th>
<th>Calf feed (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 14</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>15 - 28</td>
<td>5.5</td>
<td>125</td>
</tr>
<tr>
<td>29 - 30</td>
<td>5.5</td>
<td>300</td>
</tr>
<tr>
<td>31 - 32</td>
<td>4</td>
<td>300</td>
</tr>
<tr>
<td>33 - 42</td>
<td>4</td>
<td>500</td>
</tr>
<tr>
<td>43 - 60</td>
<td>4</td>
<td>600</td>
</tr>
<tr>
<td>61 - 90</td>
<td>3</td>
<td>1000</td>
</tr>
</tbody>
</table>

Cost of feeds at the station

From Figure 1 it is observed that fodder was the highest feed input i.e. Rs 1.5 millions followed by cowfeed. This was because fodder was bought from two contractors on a daily basis while the other feeds were bought as and when required.

Breeding and experimentation

Reproductive efficiency

Table 7 shows the mortality rate has increased but was low. The conception rate with AI had almost doubled and with natural service it was almost the same in 2000 and 2001.

Heat detection

It was noted that in 2000 observed heat detection was the most used method (74.4%). But in 2001 it had dropped to 63.8% while the use of prosolvin, which is an estrus synchronising hormone, had increased from 25.6% to 36.2% during that same period.
Figure 1: Total cost of feeds (Rs ‘000s) per annum at station

![Cost of Feeds](image)

Table 7 Reproductive performance in 2000 & 2001

<table>
<thead>
<tr>
<th>Reproductive performance</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
<td>162</td>
<td>116</td>
</tr>
<tr>
<td>Conception rate with natural service</td>
<td>49.7</td>
<td>50.0</td>
</tr>
<tr>
<td>Conception rate with Artificial Insemination</td>
<td>28.6</td>
<td>50.0</td>
</tr>
<tr>
<td>Birth</td>
<td>39</td>
<td>51</td>
</tr>
<tr>
<td>Still Born (%)</td>
<td>2.6</td>
<td>5.1</td>
</tr>
<tr>
<td>Aborted (%)</td>
<td>5.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Experiments

A number of experiments were started since 1999. Some recommendations have already been adopted either at the farm or national level. Some of the experiments are listed below:

- Preparation and use of an emergency bagasse-based feed for cattle during fodder shortages.
- Preparation and utilization of Urea Molasses Multinutrient Blocks (UMMB)
- Chipping of fodder

Health care

Hygiene

Cleanliness in terms of dirt, waste and left over feeds of the different buildings as well as the accessories associated with them were assessed. It was observed that approximately 70% of the byres, feeders and drinkers were kept rather clean. Poor hygienic conditions were observed mainly in the old byres. The milk room and feed stores were in a good condition.

Disease occurrence (main) and their control

Analysis showed that the occurrence of diarrhoea had increased from 28% to 40% over the past two years. Worm infections (25% occurrence) were also a major problem, which affected mostly the calves. Mastitis (11%) and injury (13%) had also some negative impacts on the health of animals.
Preventive measures adopted at the station included: provision of clean water and feed, good drainage, keeping dung far from the byres and no stagnation of water in the yard or byres. The sheds were disinfected every 15 days and/or every month using Barricade. Control of flies was done with Nzi traps and private firms did control of rats. Deworming was carried out at regular interval.

**Production parameters**

*Performance of animals*

It was found that the calving interval was short (13 - 14 months) and the service weights of the breeds were being respected. Performance of animals was also assessed by milk production and the average daily gain in weight. The average milk production ranged from 8 to 10 L / cow / day for Creole and Cross breeds whereas for Friesian it was between 10 to 12 L / cow / day. **Figure 2** shows that there has been a more or less steady increase in the ADG from the time when the station has been taken over and it has been maintained in year 2000.

**Figure 2** ADG (gd⁻¹) in weight for young animals at the station in 1999 & 2000

![Graph showing ADG (gd⁻¹) in weight for young animals at the station in 1999 & 2000](image)

**Visual assessment**

*Conditions at the station*

As visually assessed, the milk room was under proper conditions since it was well aerated and had good light penetration. One of the feed stores was under good conditions, while in the other the feeds were kept on damp, moist condition. **Table 8** shows some of the conditions at the station. Flies were quite a problem since 29% of the byres had high percentage of flies especially with stomoxys. To control parasites, the officers had used flytraps of blue colour. Snip was used successfully in the nursery to control flies.

*Waste disposal*

The amount of waste produced at the station was about 3 tonnes/day and it was disposed by two systems. Liquid wastes drained away in the sewage system through constructed drains and solid
wastes were removed by trailers and subject to manure stacking. A “Mechanical Manure Remover” was available but was not installed, as it required modifications.

Table 8 Conditions at station

<table>
<thead>
<tr>
<th></th>
<th>Byres</th>
<th>Milk Room</th>
<th>Feed stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>57</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ventilation</td>
<td>57</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>57</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

Record keeping

Since the station is involved in research work record keeping plays a vital role in experimentation. A number of records were kept at the station each having specific and distinct purposes. The data were recorded accurately by the SRA & RA and kept in the following books: Strength and Control Book, Calving and Breeding Book, Milk records & Milk Revenue Book, Labour Distribution Book, Request Book, Health & Vet Book, Sales Book, Weighing Book, Assessment and Service Book.

Marketing

Sales of by-products

Unproductive and stunted animals were sold for slaughter at Rs 30.00 to 45.00 kg⁻¹ to public and Mauritius Meat Authority (MMA). Animals for breeding were sold at a higher price (Rs 55.00 kg⁻¹) because these animals had good body conditions and were in good health. Those that had health problems were sold on human ground on carcass weight to MMA.

Manure was essentially sold to public either in bags or by lorry load. It was found that from 2000 to 2001, the number of bags sold had decreased from 3241 to 1893 units which represent a 38% decrease while the amount sold by lorry load had increased from 260 tons to 414 tons (a 38% increase).

The total milk production in 2001 was 112,368 litres (L) whereas in 2000 it was 123,774 litres (L). Maurilait has been the largest buyer in year 2000 (about 57,000L) but this amount has decreased in 2001 to 50,000L. People living in the vicinity also bought a large amount of milk in 2001 (37,000L) and AMB had increased its consumption from 7,000L in 2000 to 13,000L in 2001.

Expenses in 2000 and 2001

Table 9 shows the expenditures at the station for the past two years. It is observed that the highest inputs were wages, feeds, concentrates and fodder. On the other hand, analysis showed that the revenue had decreased and the expenses had increased resulting in a higher deficit of more than Rs 4.3 millions in 2001.

Table 9 Expenditures in 2000 and 2001

<table>
<thead>
<tr>
<th>Source</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>76,665</td>
<td>122,556</td>
</tr>
<tr>
<td>Water</td>
<td>96,731</td>
<td>96,350</td>
</tr>
<tr>
<td>Telephone</td>
<td>22,946</td>
<td>24,609</td>
</tr>
<tr>
<td>Feed &amp; Fodder</td>
<td>2,705,477</td>
<td>2,705,477</td>
</tr>
<tr>
<td>Drugs</td>
<td>95,794</td>
<td>119,983</td>
</tr>
<tr>
<td>Materials</td>
<td>167,730</td>
<td>648,228</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5,273,563</td>
<td>5,825,423</td>
</tr>
</tbody>
</table>

Note: Wages of SRS & RS had not been taken since they were not considered as people working at the station but only posted there.
DISCUSSION, CONCLUSION & RECOMMENDATIONS

Implementation of research techniques

The beneficial results obtained from the station were being transferred successfully to the farming community via the Extension Division of AREU. One such example is the use of bagasse-based feed. The farming community has now adopted the use of this feed because it can be used during periods of shortages and droughts.

Some experiments have given satisfactory results but have not been adopted yet because of the high costs involved. One example was that though the beneficial effects of UMMB have been duly analysed, farmers have not used it because of its high cost (Rs 5.50 kg⁻¹) (Bheekhee, H., pers. comm., 2002). Nevertheless, UMMB was used at the station since it was prepared at a lower cost (Rs 3.00 kg⁻¹). Had a favourable price been provided to the farming community and had the effect of fodder scarcity been considered, the use of UMMB could be expected to increase. In this context, the use of UMMB has been adopted on deer farms whose owners could afford to meet the cost.

Another important technique devised at the station was the chipping of fodder using an electric chipper. This technique provides a number of advantages. There is less wastage of fodder; increased intake and animals can be provided with a known amount of fodder. A common farmer may not be able to buy an electric chipper, but he can afford to use either the manual or diesel operated chippers since chipped fodder has produced conclusive results at the station. A number of small cowkeepers will be able to remain in business in case the ongoing experiments provide similar positive results. Then the future of the farming community can be assured.

Infrastructure

The infrastructures of most of the buildings are old. This was understandable because the farm dates back to 1920. But it was quite surprising that after 80 years, most of the byres were still functional though the feeders were old and not well adapted to feeding of animals. Windows were in a poor state allowing entry of flies. Hence, animals were exposed to climatic variations and susceptible to pests and diseases.

The ventilation system was not well designed and was in a poor state. It is very important to have a good ventilation system in order to maintain the inside air near the purity level of the atmosphere (Mathur, 1990). Light was not well provided due to the layout of the building except in the case of the nursery where Perspex sheets were used.

Mathur (1990) stated that direct sunlight, apart from possessing health and growth promoting properties, has also a distinct germicidal action by virtue of its ultraviolet rays. He added that direct sunlight also acts as a powerful disinfectant. Hence, improvements in the layout of the byres are necessary to manage the animal properly and to improve performance of the animals.

Pasture management

A large portion of the pasture area at the station was not provided with proper care since the bulk of fodder was bought. Ma Poon and Bundhoo (1988) stated that the possibility to create new fodder areas in Mauritius is limited. Also conversion of land would result in a decrease of fodder availability. The station, like the cowkeepers relies on sugarcane tops during the harvest season from July to November, as it constitutes the bulk of the local feed. However, there are disadvantages of seasonality and nutritional limitations with sugar cane (Ma Poon & Bundhoo, 1988) while shortages in fodder occur from April to June (Arlandoo, 1988). The farm is situated in the humid region where the annual rainfall of about 3000mm compared to other regions in Mauritius for example, in the North or South West where the annual rainfall is 790 mm (Ramchurn, 2001). Thus, better climatic conditions are prevalent at the station for the cultivation of pastures. So, the land available at the station should be used in the best possible way. A good pasture management with proper irrigation and fertilisation could be established to alleviate problem of fodder shortage (Ramchurn, 2001).
Labour management

A majority of workers admitted that they liked their jobs and were satisfied with the work allocated to them. Satisfaction among manual workers could be attributed to a sound supervision from the head officers and a proper personnel management. Strategies adopted so far at the station have had a positive effect on labour efficiency. Workers were employed as labourers but given an allowance to act as stockman. This acted as a cash incentive. Workers worked on a shift system which implied that animals were provided with proper care right from early morning up to late evening.

In the past, the station had faced problems of ageing workforce (Anon., 1991) but these days they have a younger labour force, which could guarantee the future of the farm. The advantage of having a young workforce is that they are able to carry out more laborious work such as feeding, milking, manure removal and day-to-day maintenance of the station than old ones.

One major constraint at the station was the high rate of absenteeism among manual workers and labour shortage. Acker (1971) pointed out that labour requirement for dairy cattle is relatively high because each animal has to be fed and milked daily. So, lack of labour would result in disruption of the daily programme, accumulation of works and extra tasks for those that are present. The survey has also revealed that absenteeism was higher on Mondays and Tuesdays as compared to Sundays. This is explained by the fact that workers were paid overtime on Sundays. This resulted in absence on Mondays and Tuesdays because the opportunity cost outside the station was higher.

The problem of labour shortage was partly alleviated with an increase in the sales of manure by lorry. Workers were less involved in filling bags and they were directed towards others tasks. But, with the imminent introduction of mechanisation at the station, the problem of labour shortage could be tackled.

Workers admitted that they were not provided with proper working conditions. This could act as a disincentive could well explain why 40% of the manual workers were not satisfied with their work. The workers did not have a personal bathroom. Taking into consideration the nature of their work, which involves unpleasant smell and working with manure, workers should not be deprived of proper hygienic conditions. Workers also complained that their messroom was small and uncomfortable since it was located close to the byres and manure disposal area. These factors would easily outweigh the benefits generated by a sound personnel management. Hence, proper working conditions have to be provided to the workers to optimise on labour productivity.

Feeding management

Experiments have shown that animals may live for more than 100 days without organic food but they will die in 5-10 days when deprived of water (Bannerjee, 1991). Water was not a problem at the station since it was provided ad lib, but wastage occurred with the drinkers made of concrete. The way the drinkers were located restricted water availability to animals in pens. The animals would not get enough water for digestion and metabolism after tremendous volume of feed consumed. So amendments should be brought at this level especially when water constitutes about 70% of the animal’s body and about 87% of milk (Mathur, 1990).

Scientific officers had worked on the feeding rations where animals were fed according to their growth stages. Ma Poon and Bundhoo (1988) stated that one of the prerequisites for optimum animal performance is the availability of adequate and regular supply of fodder. This is why fodder consumption was highest at the station. But since fodder alone did not provide all the nutrients needed for maintenance, milk production and pregnancy, it had to be supplemented with concentrates.

A large amount of cowfeed and cotton seed cake was used at the station. Experiments have shown that it is more suitable to use cowfeed in wetter areas than cotton seed cake since milk production is highest (Boodoo, Ramjee, Hulman, Dolberg & Rowe, 1988). But another reason for the use of concentrates was that the fodder supplied at the station was often of low quality with low protein and high fibre content (Table 4.1 in Appendix 7 shows the nutritive value of feeds supplied to the station). Cotton seed cake was also used due to its high amount of crude protein (41.1%) compared to cowfeed (11.8%).

Molasses was used mainly to feed lactating cows because according to Bannerjee (1991) molasses act as an appetiser, as a source of energy, stimulate rumen microbial activity and provide trace elements. It is often used with 2.5 % urea at CLRS. It has been found that supplementary feeding of cows in...
early lactation will not only lift immediate yield but will also increase the persistency of lactation so that the total lactation effect may be 3 - 5 times higher (Moss, Bishop & Chopping, 1983). This could explain why animals at the station were producing more milk from the time when AREU took over the station.

Different strategies were adopted for growing and pregnant heifers because it is important that growing heifers are fed to grow and not to fatten (Acker, 1971). To avoid fattening and to cause maximum rumen development, heifers were provided with high amount of sugar cane tops and fodder supplied with cowfeed concentrates.

The level of concentrates was kept low because with high levels of energy, there may be deposition of fat in the udder during growth. Therefore, there will be less development of the secretory tissues resulting in lower production (Acker, 1971). This shows that the station has adopted efficient feeding programmes. The same techniques could be adopted by the small cowkeepers and this would help them to manage their heifers more efficiently. Farmers will not make unnecessary investment in feeding large amount of concentrates to their heifers.

The general management and feeding of growing bulls were quite similar to that of heifers (Payne, 1990). Feeds were fed in such a way that the bulls could be brought into service as early as possible. Supplementary feeds were also provided to breeding bulls to cater for the low quality of fodder supplied to keep them in a vigorous physical condition and care was also taken so that they did not get fat (Payne, 1990).

Calves’ ration was derived from a booklet known as the “Nutrients Requirements of Dairy Cattle”. The animals were initially weaned at 90 days. Preliminary experiments at the station have shown that instead of using whole fresh milk, a milk replacer known as “Cremolac” gives promising results. The advantage with this product is that animals can be weaned at 70 days. Early weaning would mean that milk is replaced by cheap fodder. This could be of economic importance to the small cowkeepers who can effectively increase their overall profitability by weaning the animals earlier.

**Husbandry practices**

Proper management techniques and good husbandry practices have been adopted at the station. This could be explained by the low mortality rate. Proper care was provided to the animal at pre and post calving periods. This involved assistance during calving, proper feeding techniques and adequate health care to the animals. It can be inferred that pregnant and newborn animals were efficiently managed at the station.

Other husbandry practices involved at the station were good hygienic conditions. This is important since cleaning helps to preserve the health of animals and indirectly helps to preserve the health of people who keep them (Mathur, 1990). Proper sanitation and control measures were provided to fight against diseases since it is known that efficient and economic husbandry is dependent upon the health of the herd (Hill, 1988).

Disease occurrence was kept as low as possible with the help of competent persons which operated upon recommendation made by the veterinary officers from the Ministry of Agriculture. Techniques were devised to control flies and disinfections were carried out at regular intervals. One efficient method was the use of baits such as “Snip”. This material when placed on a “gunny” bag attracted all the flies, which were killed. It is known that farmers face problems of flies since they keep manure heaps very close to their sheds. This technique could well be an option for them to control flies. Farmers may adopt judicious use of disinfectants as it delimits disease, prevents its onset and destroys disease-producing organisms (Mathur, 1990).

One major problem at the station was the high occurrence of diarrhoea. Diarrhoea is a confounding factor in calf research and may be due to dietary origin or contamination of bucket by flies (Morris, Arundel & Molennan, 1983). These were overcome by reducing the intake of milk, preventing overfeeding of animals and good hygiene.

**Efficiency of reproduction and production**

Reproductive performance is one of the major factors which influence the efficiency of livestock production. The station was under efficient management since the calving interval was short i.e. 13 -
14 months compared to past records at the station, which showed that the calving interval was as high as 15 - 17 months (Anon., 1991). Research has also shown that under local conditions, the calving interval was about 15 months (Sibartie, 1988). This short calving interval may be explained by proper timing of insemination, efficient pregnancy diagnosis and proper nutrition. As a result lifetime of milk production would be increased, the number of offsprings born and hence the net income.

The conception rate whether with AI or natural service was about 50%. This was quite reasonable when compared to local farmers but was low under tropical conditions where it ranges from 63-71%. In fact, a research carried out showed that the conception rate on smallholder farms was about 36%. So, there is a need to improve heat detection techniques, timing of insemination and fertility of the cow to improve reproductive management.

Efficiency in reproduction has helped in improving milk yield. The average milk production ranged from 8-12 L / cow / day whereas in the past it was only 6-9 L / cow / day (Anon., 1991). Optimum milk production could be attributed to proper nutrition, low percentage of disease and efficient management of the animals.

The station proves its efficiency in terms of the constant average daily gain (ADG) of 550g / d of the animals in the year 2000. Compared to the previous management, the ADG was very variable ranging from 162 - 467 g / d (Anon., 1991). A research showed that the ADG among the small cowkeepers was 334 g / d (Boodoo et al, 1988). Hence, the local producers could use the methods devised at the station to improve their farming conditions.

**Record keeping**

Since this is a research station, the importance of records should be emphasised. So, all input and output data were recorded efficiently by competent persons. Records were kept according to the herd goals and production parameters. The most important records pertaining to the cow were calving dates, breeding dates, milk and butterfat production. These records provided a good indication of the performing ability of the cow and it also helped in routine management of the cow herd. Records showed how readily the heifers conceived when bred her length of pregnancy and calving interval (Acker, 1971). On the whole, records were used to monitor the genetic merit of each animal. Computerising the system of record keeping could bring further improvement at the evaluation level. Computerisation would prevent duplication of efforts and eliminate the problem of keeping a number of books.

**High cost of production**

Ramkissoon (1988) stated that cattle are a costly resource and cattle experimentation become even costlier when adding the needs of housing, feeding and monitoring of variations. This confirms the result obtained from the survey, which revealed that the cost of production was very high. Analyses of data have shown that the expenses were increasing while the revenues were quite stagnant. As a result, the deficit during the past two years has increased. The increase in expenses could be attributed to an increase in cost of materials. The station is in a rebuilding and expansion phase. Thus, renovations and repairs were necessary to improve the state of the farm. This contributed to the high expenses.

The revenues were low because sales were done well below market prices. The animals produced at the station were sold at Rs35-55 kg⁻¹ LWT while the market price for meat was Rs120-160 kg⁻¹. Similarly, milk is sold at Rs 18.00 L⁻¹ on the local market whereas the station was selling milk at half of this price. These were mainly due to some government policies, which AREU has to follow. Thus, being a non-profit making unit, this deficit was not taken into consideration, since the return they expect from research work is that cowkeepers become more efficient and profitable.

**CONCLUSION**

Success in dairying depends largely on the proper care and efficient management of the herd (Bannerjee, 1991). The study has shown that from the time AREU took over the station, efforts from researchers, managers and workers have been maintained to improve the state of the farm. Analyses of
data showed that they have been successful to a large extent, but there is always room for improvements.

It should be pointed out that the new team has taken only three years to bring the station to a satisfactory level and this is shown with an improvement in animal productivity and performance. More time should be given to this new team before analysing their competencies and their approach to research work. Some research projects, which are farmer oriented, are being implemented at the station. Investments that are poured into research may not produce immediate results but will definitely have an impact on the livestock sector as a whole. From the results it can be concluded that:

- Research is carried out for the benefit of small-scale farmers.
- Labour was efficiently managed but workers were not provided with good working conditions.
- An optimum dietary management has resulted in better animal performance compared to the past and the local community.
- Good husbandry practices have improved productivity on the farm.
- Efficiency in production and reproduction was confirmed with short calving interval (13-14 months), high ADG and optimum milk production per cow.
- Records were efficiently kept at the station allowing better farm planning, control and evaluation.
- Infrastructures (especially in old byres) were not in conformity to modern designs, thus, reducing efficiency in animal production.
- The major constraints to research were labour shortage and high absenteeism which usually disrupted day-to-day running of a farm.
- The cost of research was very high but was outweighed by the benefit derived by small-scale farmers.

RECOMMENDATIONS

In the future, deeper and more detailed assessment of every management aspects should be carried out to get a clearer view of the management operations involved at the research station. From the study the following recommendations can be made:

(1) Emphasis has to be laid on improvement of the byres. The feeders and the drinkers have to either be rebuilt or modified to increase efficiency in feeding.
(2) Record keeping need to be computerised to save labour and time.
(3) There is a need to maximise on production of pasture (e.g. legume species) on the available land to meet demand of animals and alleviate problems of poor quality fodder.
(4) Introduction of mechanisation will reduce problems of labour shortage. The mechanical manure remover and the line milking machine have to be made operational as quickly as possible.
(5) There is a high need for AREU to review its price policies to decrease to some extent the large deficit encountered by the station.
(6) Labour has to be recruited at the station. This will help in better distribution of work with adequate care to animals, pasture and buildings.
(7) The hygienic conditions of the old byres need improvement as these are acting as disease vectors. This is outweighing the benefit derived from proper sanitation in the other byres.
(8) Provision has to be made for better working conditions for the workers.

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REFERENCES


THE USE OF INFORMATION STRUCTURES AT THE
COGNITIVE LEVEL IN THE DAILY MANAGEMENT OF
INFORMATION BY SMALL-SCALE LIVESTOCK KEEPERS IN
A VILLAGE IN MAURITIUS

G Naidoo

Ministry of Agriculture Food Technology & Natural Resources

ABSTRACT

A study conducted in a village in Mauritius revealed that small-scale cattle keepers manage information regarding their cattle keeping activities through nine information structures at the cognitive level. These represent building blocks leading from a basal information to a goal in their search for information. These information structures are ranked in a hierarchy of importance from their perspective. It gives an insight into how small-scale farmers manage information from sources and using their working knowledge. This is relevant for technicians of the agricultural sector working closely with small farmers.

Keywords: Small-scale cattle keepers, Information structures, Working knowledge.

INTRODUCTION

Studies of agricultural information have commonly used an actor, source or node approach, such as the Extension officer, an Extension Organisation or a University respectively. The present study focuses on a content approach in the structure and use of information obtained from local sources from cattle keepers’ perspective in a selected area in Mauritius (Canot / Gros Cailloux). The purpose of the study is to understand how a population of cattle keepers in the selected site manage information that is accessible to them, and find out whether there is a problem regarding their understanding and use of information at their level from their own perspective. This means exploring how the cattle keepers obtain information, how they structure the information content acquired in their memory or in print to serve as a map to guide them in using information, and whether they store it and communicate it.

METHODOLOGY

The research methods consisting of a three-stage iterative process termed ‘OPI’, using ethnography and grounded theory with in-depth interviews, direct and participant observation has been described in detail in a previous paper (Naidoo, 2001). This present paper focuses on the emergence and interpretation of the structures of information. The study uses a qualitative approach to gain some insight into the phenomenon of management of information (Krippendorff, 1980; Patton, 1980), which assumes that there are no readily existing social facts or data in nature, instead they have to be ‘constructed’ through interpretations by the researcher in a qualitative analysis. Thus a picture can be obtained of a phenomenon which allows decisions to be taken when the research is well immersed in the environment from which reality is being constructed. This paper uses as method the analogy of Downs and Stea (1977) of ‘cognitive mapping’ to describe the mental processes through which people try to understand the world around them, organise their representations and interpretation of their information environment and go about their daily activities. It also uses the analogy of Jones, Rolls and Tranter (1987) of describing the management of information as a filing system with filing cabinets at the level of memory in which information is structured in separate ‘files’, and in an organised way to aid search and recall of information content whenever the need arises. The way farmers receive, search, use and manage information from sources is represented as structures of information at the level of memory. The research reports on and classifies respondents’ understanding about happenings.
in their particular settings to gain some insight into social phenomena. The task of the researcher is to interpret the issues from the perspectives of respondents and then present the findings back to them for their recognition and confirmation of the conclusions being drawn from the data.

RESULTS

Content analysis of the responses arising from the interviews and participant observation was necessary in order to derive the structures of information used by the cattle keepers. Their statements were compared to draw out resembling patterns of ideas, and the patterns were then collapsed into concepts to construct the structures of information. A concept is thus an idea which includes a number of observations which have common characteristics. Accessibility (Table 1). These structures of information represent building blocks leading from a basal information to a goal through intermediate information needs. The cattle keepers seek information from sources or retrieve it from their own working knowledge in a hierarchy of information content and in a methodological cognitive mapping. The information structures can represent cognitive maps of how the cattle keepers organise their representation and interpretation of their information environment, and how they may organise their search for and use of information under these content headings. The sources of information can be internal or external to the farming system. Keeping detailed records seems to be difficult for farmers with little formal education, and they appear to resort to mental recall to manage information.

The derived structures of information are ranked according to order of importance (Table 2) using the ranking of information contents (Table 1).

The Nutrition information structure

What is most important to the cattle keepers is at the top of the structure (Figure 1), in this case Animal Growth and Production. To achieve this goal, they need to have information on the feeding aspects, and this involves information and working knowledge of nutritive value of feeds. The cattle keepers are satisfied from a customer-care consciousness point of view that concentrate feeds are accessible at their gate as home sale, even at higher cost.
The use of information structures at the cognitive level in the daily management of information by small-scale livestock keepers in a village in Mauritius. G Naidoo

**Table 1** Rank order of importance of information contents

<table>
<thead>
<tr>
<th>Information content</th>
<th>Frequency score (n = 59)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder accessibility</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>Milk sale</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>Concentrate supply</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Group spirit</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Reproductive performance</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Shed improvement</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Sanitary regulations</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Land availability</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Veterinary treatment</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Loan dislike</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Burial of animals</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Stock availability</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Borrowing of cattle</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Waste feeding</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Payment for produce</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Incentives awareness</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 2** Ranking of information structures

<table>
<thead>
<tr>
<th>Information content</th>
<th>Frequency score (n = 59)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition information</td>
<td>51</td>
<td>1</td>
</tr>
<tr>
<td>Sales of produce information</td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>Veterinary information</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>Land resources information</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>Group information</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Financial information</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Cattle housing information</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Stock renewal information</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Storage of document information</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

**Figure 1** The Nutrition information structure
Cattle keepers have developed their own knowledge about feeding concentrates. They feed these in the wet form as compared to what is advised from official sources. They share concentrates purchased for their cows with their growing bulls to diversify outputs, hence their feeding levels are lesser than technical recommendations. They remember habitual names of concentrates which become fixed at the local knowledge level. Cattle keepers have acquired local knowledge on the species of fodder best suited for their animals. They are informed by their client buyers that natural grass feeding for bulls produce the best meat. Before using kitchen and other wastes, they consider appetite, palatability, and the ensuing meat quality of their animals based on their own acquired knowledge. They also consider the ethical feeding of animals before accepting use of technical recommendation on waste feeding. The duration and regularity of concentrate sales at sale points are not considered satisfactory and client oriented. Fodder is collected from the field by the cattle keepers. Cattle keepers face difficulty in accessing fodder resources from their local surroundings because of fencing of traditional fodder lands by the sugar estates. The cattle keepers are not quite aware of other types of feeds, their price and supply as the communication methods about these other types of concentrate sales are not reaching them at the individual level. People who are engaged in agricultural activities on sugar estates have more access to information on availability of fodder, otherwise there is competition for fodder between the cattle keepers and the sugar estates. There is a lack of a reliable communication of information about fodder among the cattle keepers. There is therefore a feeling of exclusion during periods of fodder scarcity. Further loss of fodder resource is envisaged with a planned reallocation of state land for a pig rearing project which poses another problem of free accessibility of fodder. The cattle keepers fear that their livelihood is at risk, especially as fodder has to be carried mostly on the head from the field to their homes. The purchase of concentrate feeds depends on carriage of these feeds from sale centres to their homes, which means the need for family labour. The cattle keepers go about from the basal information of how much family labour is available to do the work of carrying feeds and fodder to their animals from their immediate environment.

The Sales of produce information structure

The main concern of the cattle keepers in this information structure (Figure 2) is that sale of their produce should be from their home. These are mainly live cattle, milk and manure, with wild pepper (*Schinus terebenthifolius*) being an occasional produce. Cattle and milk sales are through organised and opportunity channels, whereas manure sale is of the latter type.

![Figure 2 The Sales of produce information structure](image)

The opportunity sale for cattle is done at the home level and is integrated with purchase of calves as well and usually is done on festive occasions. The cattle keepers are not themselves willing to effect sale externally because of transport difficulties and costs, irrespective of whether the buyers will resell produce at a profit. In the organised sales, the concerns for the cattle keepers are transport...
arrangements in emergency problems to animals to take them to an external buyer. Information which concerns them are regularity of transport from the marketing agency and the procedures involved in the collection of their cattle. The same concern occurs in the organised sale of milk. Aspects of quality which are on their mind are the heavy procedures for quality standards and milk tests, which result in delayed collection and conflict with the buying agency. Their feelings about this collection is painted with trust or suspicion. What is forefront in their mind is the possibility of wrong measurements by the buying agency, and less revenue for unsold produce, which makes them question the economics of their production especially with lack of records and frequency of collection. The cattle keepers claim quality of their produce is good but it is not reflected in the price paid to them. Payment is characterised by written documents as proof of sale. The basal concern in this information structure is that they should be paid for their produce at the time of collection without delays, although part payment through deposits or given word of mouth may be made at the time the agreement for sale is concluded.

**The Land Resource Information Structure**

To support their cattle rearing activities, cattle keepers make use in this information structure (Figure 3) mainly of what they have learned about use of land resources from their elders and from what they know from their working knowledge. This comes about through exposure and familiarity with the place, type and availability of fodder they go to collect daily from their surroundings. Fodder availability is dependent on land existing in the immediate environment where forage or grasses can be cut for use in cattle rearing.

![Figure 3 The Land Resource Information Structure](image)

The land resource information structure indicates that facilities for obtaining fodder is dependent on the degree of exclusion from land resources for their cattle keeping activities due to fencing of land by the sugar estates. This exclusion feeling is exacerbated by their worry about the need for sanitary regulations regarding cattle keeping coming from the sanitary authorities. They are concerned on how land is being utilised or will be utilised to support them in their cattle keeping activities through land use policies and activities of surrounding sugar estates. Their basal concern is about their need for land and whether redistribution and reallocation of land to other sectors will affect their livelihood.

**The Veterinary Information structure**

The main concern of the cattle keepers in the Veterinary information structure (Figure 4) is how to benefit from the incentives provided by the Government Veterinary Services. This will depend on their ability to demonstrate reproductive performance which involves natural mating, artificial insemination, pregnancy assessment, care of calving and suckling. Follow up of reproductive
The use of information structures at the cognitive level in the daily management of information by small-scale livestock keepers in a village in Mauritius. G Naidoo

Performance depends on veterinary records, which involves natural mating, artificial insemination, pregnancy assessment, care of calving and suckling. The veterinary records will be based on animal health and its maintenance through disease prevention and treatment. The latter depends on the different sources of information available in and outside the village. Cattle keepers have their own traditional methods of treatment. They then resort to the government or private veterinarian. When these fail, they resort to occult healers as there is also a belief about occult harm to their animals resulting in diseases. Death of their animals involves seeking a burial place requiring human assistance.

**Figure 4** The Veterinary information Structure

![Diagram](image)

**The Group Information Structure**

The most important concern for the cattle keepers in this Group information structure (Figure 5) is that they have their personal goals which are unlikely to be upset by other considerations. This is based on their own traditional indigenous (working) knowledge as farmers which is also used extensively. Farmer knowledge is based on access to information from sources through information seeking and information exposure.

**Figure 5** The Group Information Structure

![Diagram](image)
The use of information structures at the cognitive level in the daily management of information by small-scale livestock keepers in a village in Mauritius. G Naidoo

Access to information at the local level is based either on tapping the pool of information among peers and elders, or being exposed to the withholding of information. This will depend on whether there are common problems to be solved in which case the group spirit becomes strong, otherwise cattle keepers are individualistic in approach. The group spirit is manifested by organised group meetings. The basal information on which rests the information structure is that farmers are always faced with problems which they have to solve to continue their activities.

**The Financial Information Structure**

The most important element in this structure of financial information (Figure 6) is the improvement of their living conditions through cattle keeping. This is dependent on household savings, which are themselves dependent on the profits realised in cattle keeping activities as well as incentives received from Government for rearing cattle. Their achievement of profits is dictated by the availability of credit at the local informal level, which involves their keeping of records, their use of counting as a useful tool which they have learned by themselves informally, and on markets available for their produce. Credit management rests mainly on the use of savings’ cycle in the form of ‘citte’ at the local level.

**Figure 6** The Management of Financial Information Structure

![Diagram](attachment:financial_structure.png)

The basal information on which rests the information structure is the spirit of self reliance, characterised by loan aversion to avoid indebtedness.

**The Cattle Housing Information Structure**

The most important element in this structure of information (Figure 7) is the need for improvement to housing conditions on cattle keepers’ premises.

**Figure 7** The Cattle Housing Information Structure

![Diagram](attachment:cattle_housing_structure.png)
This depends on their aspirations and managerial characteristics which tend strongly in favour of their own house construction in concrete as against improvement of their animal shed. Improvement of human and cattle housing depends on the notion of progress from their activities, on the need for security and on availability of land for construction. All these are dependent on the construction skills which they have, and which determine the choice of materials used for their housing and shed management practices. These materials also depend on their self reliance possibilities to utilise resources at the household level and on division of tasks within the family, as opposed to the hiring of external paid labour. The basal idea in this structure of cattle housing information is their concern to sustain the household economy.

The Stock Renewal Information Structure

The priority in the stock renewal information structure (Figure 8) is the need for the purchase of a young calf at the individual cattle keeper level. This depends on the main sources of stock availability information, which rests on the official sources of purchase like the Ministry of Agriculture and the unofficial sources like the butchers, and in-village or out-village cattle loans among cattle keepers (termed entre deux), or even their own production.

![Figure 8 The Stock Renewal Information Structure](image)

Purchase or loan of new stock is judged on the age, breed and quality of the animals as well as on mode of payment. The butchers are perceived by the cattle keepers to be quicker providers of service with facilities of payment. The official sources are characterised by longer obtainment procedures for the animals and by the limited number of animals to be sold. The sources of information also differ in the sense that some are home and others away-from-home purchases of cattle, and the latter case is dependent on the transport of these animals involving an important element of cost to the cattle keeper. The basal element in the stock renewal information structure is the concern of the cattle keepers to increase their stock.

The Storage of Information on Documents Structure

In this storage and retrieval information structure (Figure 9), the emphasis is on access to inputs needed to carry out their cattle keeping activities. There is an awareness that to accede to inputs, some documents are important administratively while those which are not considered important are not allocated resources as far as their keeping is concerned. Documents which are old and unused are discarded by burning.
The use of information structures at the cognitive level in the daily management of information by small-scale livestock keepers in a village in Mauritius. G Naidoo

**Figure 9** Storage of Information on documents structure

- Access to inputs
- Administrative importance
- Documentation
- Retrieval
- Safe keeping

The administrative importance of documents is dependent on their being present when needed, reinforced through copying of these so as to keep originals while the copies are handed to concerned officers. In the first instance, documents have to be retrieved. There is realisation for retrieval time to be minimal, and for maintaining a state of readiness for providing the kept information. Access to the documents is by elder family members, usually womenfolk in known locations in the house. What concerns the cattle keeper basically about documents is their safe keeping for easy retrieval.

**CONCLUSION**

The results of the study show that nine main structures for managing information by its contents are used by the cattle keepers. These include substantial use of their working knowledge, learned mainly from family elders, as well as deriving information from other internal and external sources. The structures of information seek to explain that cattle keepers proceed in an organised and hierarchical way of cognitive mapping of contents when looking for, using, storing and communicating information relevant to their needs. The research results have important implications for reorienting future work and policy to address information needs of the small-scale cattle keepers.

**REFERENCES**

A CASE STUDY OF FARMER PARTICIPATORY RESEARCH: MINIMUM TILLAGE OF MAIZE ON SLOPES IN RODRIGUES

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ABSTRACT

Maize is the most important crop in Rodrigues, being grown on flat land as well as on slopes, whether terraced or not. Since land preparation cannot be mechanized on slopes, the cost of labour for manual land preparation was identified in a survey as the most important constraint to maize production. Moreover, when land is ploughed at the beginning of the rainy season, the soil is exposed to erosion by water. A possible solution to this problem consisting of minimum tillage was proposed in a participatory planning workshop. Since it involves the use of herbicides with which most maize planters in Rodrigues are not familiar, it was necessary to enlist the participation of planters in the choice of practical options, in the design of trials to test them and in the implementation of the trials on their farms.

Ten trials were planted in 1999, nine in 2000 and three in 2002. Four treatments were tested: a control consisting of the normal practice of manual ploughing with a garden fork; a minimum tillage practice consisting of ploughing narrow strips only; and two zero tillage practices, one consisting of clearing weeds with a hoe and the other of spraying a herbicide. Planting holes were then dug for sowing the maize.

Most of the trials failed because of drought and, in the end, yield data were obtained from six trials only. At none of the six sites did the tillage treatments have significant effects on yield. This means that ploughing had been of no benefit. All three minimum/zero tillage practices required much less labour than the control, and the savings in labour in the best treatment amounted to more than seven times the cost of purchasing and applying the herbicide.

The project was evaluated in a workshop in June 2001 attended by 42 persons comprising planters, extension officers and other stakeholders. Everyone agreed that when maize is grown without tillage, erosion is reduced. A large majority agreed that the maize emerges and grows normally, that weeds are not worse and that less labour is required. However, only one third also agreed that the maize yield is normal. Two-thirds mentioned that they were prepared to change their maize planting method but, because yield is the first criterion in the selection of new practices, demonstrations may still be needed to convince more planters.

Keywords: on-farm trials, no till, soil erosion, labour bottleneck

INTRODUCTION

Maize is a very important crop in Rodrigues. It is grown by all producer groups practically everywhere, from the coast to the interior, on good and poor soils, and on flat and slopy lands. Under the current rainfed and low-input cropping system, yield is low, averaging 1230 kg ha⁻¹ (Govinden et al. 1998a). The main causes of the low yields are cyclones, droughts, damage caused by stray animals, and low soil fertility. With the exception of cyclones, these causes are being addressed directly or indirectly by the Agricultural Services with the support of various institutions.

The cost of production is relatively high, essentially because of the high cost of labour. Consequently, the profitability of maize is low as a result of the low yield and the relatively high cost of production. The low profitability in turn explains the steady decline of production over the past decade.
However, there is still much interest in maize and, in 1997, 72% of the current producers were interested in expanding the area devoted to maize and 73% of those who had stopped production were willing to resume it, subject to certain conditions (Govinden et al 1998a). Both groups sought help to overcome the problems of labour scarcity and high costs through the mechanization of land preparation. A contract tractor service has been in operation for several years. But many plots are not suitable for mechanization because of steep slopes. On such slopes, one possible way to reduce labour requirements is to reduce tillage.

Minimum tillage is a common practice worldwide. In highly mechanized production systems, such as grain production in the USA, the number of passages of equipment for land preparation is reduced mainly to save energy. In other instances, such as minimum tillage for sugar cane in Mauritius, the soil is not prepared before planting. Such no-till systems save energy as well as protect the soil from erosion.

In Rodrigues, maize planters usually plough their fields with garden forks after the first rain has softened the soil. This work is laborious, time-consuming and hence, costly if labour is hired. Moreover, the soil is exposed to erosion by water. Soil erosion is a major concern in Rodrigues. Agriculturists, livestock and crop producers alike, are under pressure from the community to adopt practices which minimize erosion. Minimum tillage and zero tillage are two such practices which maize producers can envisage. Other practices such as bench terracing are also effective, but they are expensive.

Some of the minimum and zero tillage systems involve the use of herbicides with which most Rodriguan maize producers are not familiar. It was therefore essential at the technology development and testing stages to choose an approach which would ensure a high rate of adoption.

Up to now in Mauritius and Rodrigues, the approach in research and development has been the conventional two-phase approach. It consists of technology development or adaptation by researchers on stations or on farmers’ fields, followed by technology dissemination by extensionists using a combination of methods such as demonstrations, visits, meetings, talks and recommendation documents. This approach is reckoned by many reviewers and donor agencies not to have been particularly effective in bringing about improvement in agriculture in developing countries (e.g Chambers et al 1989). They recommend more pro-active approaches referred to in the literature as participatory technology development (PTD) or farmer participatory research (FPR).

In these approaches, farmers are viewed as participants in change rather than recipients of advice and services. The full participation of farmers at all stages of technology development is seen as a precondition to the successful improvement of production practices and systems and hence, to agricultural development.

The effectiveness and usefulness of the FPR approach are yet to be demonstrated in Mauritius and Rodrigues. Only one case study, that of the optimum density of tomato in Mauritius, has been published (Govinden et al 2001). Several of the officers of the Agricultural Services of Rodrigues have been trained in the FPR approach but, as at 1999 when this study was initiated, no FPR project had been undertaken in Rodrigues.

The study reported in this paper had two objectives. The first was to investigate minimum tillage as a solution to two important constraints to maize production on slopes in Rodrigues, viz labour scarcity and high cost, and soil erosion. The second objective was to assess the usefulness and effectiveness of the FPR approach. The emphasis of the paper is therefore as much on the research results as on the process of bringing about improvement in production practices.

**METHODOLOGY**

The farmer participatory research approach is built around a set of activities in a logical sequence. Different methods may be used to accomplish the activities. Depending on the circumstances, some may be more appropriate and effective than others. In this paper, the subtitles and sequence of activities proposed by Reijntjes et al (1992) are followed.
Getting started

The project on minimum tillage can be said to have originated from the study of farming systems in Rodrigues. It gave stakeholders of agricultural development a good insight of agriculture and farmers in Rodrigues (Berthelot et al 1996), and set the stage for subsequent activities.

Looking for things to try

With respect to maize, a clearer understanding of the situation emerged from the socio-economic survey of producers and the identification of production problems (Govinden et al 1998a). Current maize growers and those who had stopped maize production did not rate labour scarcity and high cost and soil erosion as the most important problems; drought, cyclone and damage by stray animals were all more highly rated. However, both groups of producers indicated that mechanization of land preparation was a precondition to increasing maize production.

Subsequently, representatives of all stakeholders, viz farmers, researchers, extensionists, community leaders, NGOs and policy makers met in a FPR seminar and ranked the usefulness of minimum tillage first among research projects. The development of drought-tolerant varieties came second (Govinden et al 1998b).

Designing experiments

The protocol for the trial was also discussed and finalized in the above-mentioned FPR seminar. Objectives, treatments, design, duration, sites, planter groups, data collection, follow-up and the role of each stakeholder were covered.

Trying things out

This step corresponds to the implementation phase of the traditional research project cycle. Ten trials were planted in 1999, nine in 2000 and three in 2002. Trials were planned for 2001 but, because of drought, none was planted. In 1999, there were four treatments:

1. a control consisting of ploughing with a garden fork;
2. a minimum tillage practice consisting of spraying of a herbicide followed by ploughing of narrow 20 cm-bands at 75 cm intervals;
3. a first zero tillage practice consisting of clearing of weeds with a hoe; and
4. a second zero tillage practice consisting of spraying of a herbicide.

In all four treatments, holes were then dug for sowing maize at an interrow spacing of 75 cm and an intra-row spacing of 50 cm. Three to four maize seeds were sown per hill and, at three weeks, plant stand was thinned to two plants per hill. Plots consisted of 8 rows each 8 m long. The plots were laid down in randomized complete blocks with three replicates. Following the failure of the 1999 trials, it was hypothesized that the poor plant growth could have been due as much to poor soil as to drought. To verify this hypothesis, in 2000 and 2002 each main plot was split into two sub-plots of four rows each. One sub-plot received fertilizer in the form of 13:13:20:2 (13% N, 13% P2O5, 20% K2O and 2% MgO) and the other was not treated.

The choice of sites, of collaborating planters and planting dates was made by Extension Officers of the Agricultural Services. The trials were sited on slopes of varying degrees. The Services provided labour for clearing the plots, for planting and for spraying the herbicide Round-up (glyphosate) and gave the herbicide and fertilizer free of charge. The collaborating planters managed the plantation, thinned the stand, weeded the fields and helped with the harvest and with shelling. The Extension Officers measured labour used for land preparation, collected data on plant count after thinning, fresh cob, grain yield, moisture content at harvest and rated erosion after major rainfall events.

Yield is expressed as the dry shelled grain at 14% moisture content per hectare. It was subjected to a mixed model analysis of variance with treatments as fixed effects and sites as random effects. Labour used for land preparation was analysed with the same model. However, labour is not expressed as mandays per hectare for two reasons. Firstly, the extrapolation from small 24 m² plots to hectare is not...
A case study of farmer participatory research: Minimum tillage of maize on slopes in Rodrigues. *N Govinden et al.*

warranted because when the Extension Officers timed the activities, they could not account for people who laid off their tools to rest, drink water or drift away. Secondly, the labourers of the Agricultural Services have a relatively low productivity. Labour for the treatments is therefore expressed relative to the control as a percentage. This avoids the above-mentioned drawbacks.

The following parameters were used in the financial comparison of the treatments. Labour cost was set at MUR 125 per manday, which is the current cost for hired labour. The labour rate for the control, that is land preparation with a garden fork was taken to be 62 mandays per hectare, obtained from the average of 48 mandays found in the 1997 survey (Govinden et al 1998a) and of 76 mandays given by expert sources (Anon 1995). The fertilizer cost MUR 3500 t⁻¹. The cost of the herbicide inclusive of spraying was MUR 700 ha⁻¹, which is the cost charged by the Agricultural Services. And maize farmgate price was set at MUR 10 kg⁻¹.

### Sharing the results

Results obtained in 1999 and 2000 were presented at a participatory mid-term review workshop in 2001. The workshop was attended by 42 participants comprising 18 planters, 12 Extension Officers, 6 officers from an on-going EDF project on the prevention of soil erosion, 4 representatives of farmer organizations and 2 agricultural administrators. They checked the objectives, scrutinized the results, evaluated the treatments, reviewed the project’s achievements and chose the criteria on which the final results would be evaluated. The review workshop report has been circulated to all stakeholders.

### Keeping up the process

In the FPR approach, projects do not have an abrupt end. Before one project ends, follow-up activities should already have started to extend and adapt the results. Thus, at the review workshop, participating planters and representatives of planter organizations took home the results to try and officers of the EDF project chose practices to vulgarize in the zones where they operate. The publication and dissemination of this paper is yet another way of keeping up the process.

### RESULTS AND DISCUSSION

#### Technical results

Labour use for land preparation was estimated at 10 sites. There were differences between the sites, probably because of differences in soil hardness, but the site X treatment interaction was not significant. As was to be expected, there were large significant differences between the labour requirements of the treatments and hence, of their costs (*Table 1*). All the three minimum/zero tillage treatments were effective in reducing labour requirements. The best treatment – zero tillage following herbicide spraying – required only 21% as much labour as the control, and led to a saving of MUR 5450 per hectare after the cost of the herbicide (MUR 700 per hectare) had been accounted for. This represents a return of 7.8 to 1 on investment and, at first sight, it looks worth proposing to growers who hire labour. However, the next best treatment – minimum tillage: ploughing of narrow bands – also led to a saving of the same magnitude (MUR 5410 per hectare), although it required more labour. Thus, to the extent that it involved no cash investment on herbicides, it may be proposed to all growers, whether they hire labour or they use their own.

All the ten 1999 trials, four out of the nine 2000 trials and two out of the three 2002 trials failed because of drought. In these trials, the crop germinated and emerged well in all plots and grew apparently normally for six to eight weeks. Thereafter, as drought developed, the plants became stressed and eventually dried up at or soon after flowering. No grain was produced or yield was too low (< 100 kg ha⁻¹) to be reported. In these trials, even the sub-plots which had been fertilized, failed. This explains the reticence of growers to apply fertilizers to maize in areas prone to drought.

Some grain, varying from 195 kg ha⁻¹ to 715 kg ha⁻¹, was obtained in the remaining six trials. The site x treatment interaction was not significant and only means are presented. There were highly significant differences due to the fertilizer but none to the tillage treatments (*Table 2*).
Table 1: Relative labour requirements for land preparation for maize and their computed costs as a function of tillage treatments (Mean of 10 trials)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Relative labour requirement (%)</th>
<th>Cost (MUR ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing with garden forks</td>
<td>100</td>
<td>7750</td>
</tr>
<tr>
<td>Minimum tillage - ploughing of bands</td>
<td>30</td>
<td>2340</td>
</tr>
<tr>
<td>Zero tillage - weed clearing with hoes</td>
<td>61</td>
<td>4715</td>
</tr>
<tr>
<td>Zero tillage - weed killing with herbicide</td>
<td>21</td>
<td>1600</td>
</tr>
<tr>
<td>Standard error ±</td>
<td></td>
<td>230</td>
</tr>
</tbody>
</table>

Table 2: Grain yield of maize as affected by tillage treatments and the application of fertilizer (Mean of 6 trials)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg ha(^{-1})) at 14% m.c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without fertilizer</td>
</tr>
<tr>
<td>Ploughing with garden forks</td>
<td>350</td>
</tr>
<tr>
<td>Minimum tillage - ploughing of bands</td>
<td>400</td>
</tr>
<tr>
<td>Zero tillage - weed clearing with hoes</td>
<td>345</td>
</tr>
<tr>
<td>Zero tillage - weed killing with herbicide</td>
<td>325</td>
</tr>
<tr>
<td>Mean</td>
<td>355</td>
</tr>
<tr>
<td>Standard Error ±</td>
<td></td>
</tr>
</tbody>
</table>

Although very highly significant, the fertilizer effect was surprisingly small, 204 kg ha\(^{-1}\) on average, worth MUR 2040 ha\(^{-1}\) compared to an outlay of MUR 1400 ha\(^{-1}\) for the fertilizer. The return of 1.5 to 1 is too low to justify the use of fertilizer, especially since it is already an overestimation, only 6 out of 22 trials having been considered. This result underlines the fact that under the drought-proned conditions of Rodrigues, the yield of maize is conditioned primarily by seasonal rainfall and only subsidiarily by soil fertility. It also reinforces the view that under such conditions, the farmers’ strategy of not investing in fertilizer is perfectly rational; they simply cannot afford to take this risk. The take-home lesson is that attempts should not be made to vulgarise fertilizer use on maize in Rodrigues until the risk of drought has been minimized through the development of drought-tolerant varieties or otherwise.

At none of the sites were the effects of tillage treatments on maize yield significant. This shows that tillage had been of no benefit and, to the extent that it is done to improve yields, it is not justified and can be eliminated.

Project evaluation

All projects must be evaluated on the basis of their outcomes, not solely on the extent to which their objectives have been met. Sometimes projects are planned and implemented soundly and yet the objectives are not met fully for several reasons. Sometimes also, the objectives are fully met and yet, for various reasons, nothing concrete happens afterwards. This is when the approach should be questioned.

The objectives of this project were to assess the usefulness of minimum tillage as a means of addressing the twin problems of labour cost and soil erosion. The results show conclusively that the minimum and zero tillage practices were effective in reducing labour cost without reducing yields. Does this automatically mean that these practices will be adopted? The mid-term review provides evidence that they may. To a direct question on adoption, 64% of the participants in the review workshop stated that they were prepared to change their maize planting method. These, of course, could be merely adopters on paper. They will need to be followed closely and reinforced in their resolve. Another hopeful sign comes from their response to a set of questions designed to evaluate the results (Table 3). Most participants were satisfied that when maize is planted without tillage, emergence and growth are normal, less labour is required, weeds are not worse and erosion is reduced.
However, two-thirds were not convinced that yield was normal. Their skepticism is understandable given the failure of so many trials. Some participants, especially those who had not planted a trial personally, may not have realized that in those unsuccessful trials, none of the treatments, including the control, gave a yield. The effect on erosion could not be estimated because there were too few heavy showers during the trials. However, as shown in Table 3, every participant in the review workshop was satisfied that minimum/zero tillage is effective in reducing erosion. This finding provides support to the view that technical results are only part of the information needed to convince planters of the value of innovation. They can readily recognize a good practice when they see one. It points to the absolute need to include within the project activities such as visits in order to give farmers an opportunity to see the results and discuss them with other farmers.

### Table 3 Effectiveness of no-tillage for maize according to 39 participants in a review workshop

<table>
<thead>
<tr>
<th>Question: when maize is grown without tillage, are you satisfied that</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It emerges and grows normally?</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>It gives a normal yield?</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>Weeds are not worse?</td>
<td>82</td>
<td>18</td>
</tr>
<tr>
<td>Less labour is required?</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Soil erosion is reduced?</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

A central tenet of the FPR approach is to involve planters as partners in all the phases of technology development and dissemination in order to ensure relevance and effectiveness of actions. The extent to which planters participated actively is yet another measure of the success of this project. In the first stage - getting started - the farmers provided information during the rapid rural appraisal (Anon 1992). Likewise, in the second stage – looking for things to try – they also provided information in the maize survey. This was their first real opportunity to explain their problems and their needs. Thereafter, they become more active, participating fully in the participatory planning workshop organized to prepare the research and development plan. Their participation ensured the relevance of the plan to their needs. In stage three - designing experiments - they were key actors in the FPR seminar organized to choose research projects and to prepare the research protocol. Their presence ensured both the practicability of the proposed treatments and their eventual participation in the planting of these trials. In stage four - trying things out - they participated in the planting and management of the trials. However, many did not actually till the soil. This was done by labourers from the Agricultural Services and it led to problems in the estimation of labour requirements. The farmers and other stakeholders participated fully in the next stage – sharing the results – when they evaluated the results in the review workshop and suggested actions to improve participation and success rate. These include contacting planters early in the season to ensure that land is set aside for trials and the organization of farmer visits to trials. The final stage - keeping up the process – started in the review workshop and is continuing.

## CONCLUSION

The first objective of the study reported in this paper was to investigate minimum tillage as a solution to the problems of labour scarcity and high cost and soil erosion in maize production on slopes in Rodrigues. This objective has been met. The results show conclusively that minimum and zero tillage were quite effective in reducing labour requirements. Although the number of successful trials was low, the results show that such minimum and zero tillage did not reduce maize yields. They may therefore be recommended on both counts – reduction of labour and maintenance of yield. Despite the fact that it was not possible to measure erosion, planters were satisfied that the minimum/zero tillage practices should be effective in reducing erosion.

The second objective of the study was to assess the usefulness and effectiveness of the FPR approach. This assessment is not complete because other activities including a final workshop evaluation is yet to
be done. Nevertheless, there are reasons to be satisfied with the level of participation of planters and some stakeholders.

ACKNOWLEDGEMENTS

We acknowledge partial funding from the Food and Agricultural Research Council. We thank the Technical Officers of the Agricultural Services of Rodrigues for field work, and all collaborating maize planters for their participation.

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CONTROL AND / OR ERADICATION OF INDIAN CROWS
( Corvus splendens ) IN MAURITIUS

M Puttoo and T Archer

National Parks and Conservation Service

ABSTRACT

The Indian crow Bird Corvus splendens is indigenous to the Indian sub continent, Shri Lanka, Burma Malaysia and southern China. These species have spread over the past 100 years into inland and coastal areas of the Indian Ocean islands where, in the absence of natural predators, their population dramatically increased to become a pest of considerable importance. In the local context, there is scanty information on its introduction to Mauritius and it is quite possible that Mauritius has been exposed to these birds ever since ships sailed between southern Asia and Mauritius in the early 17th century, the bird being cared for on board by sailors and which flew to land on arrival of ships.

In the past, different control strategies have been implemented so as to reduce the population of crows, namely, cage trapping, shooting and feeding bait treated with poisonous insecticide but none gave any promising result. Finally, the Ministry of Agriculture, Food Technology and Natural Resources resorted to the assistance of a local firm and an expert in crow to undertake a control programme using a new chemical known as Starlicide which has proven effective against several other pest avian species in some European and African countries. The control programme lasted for twelve weeks and was carried out in close collaboration with the technical staff of National Parks and Conservation Service. The chemical Starlicide has proved to be effective and could be safely used to control these birds in the future.

INTRODUCTION

The Indian crow is indigenous to the Indian sub continent, Shri Lanka, Burma Malaysia and southern China. These species have spread over the past 100 years into inland and coastal areas of the Indian Ocean islands where in many places and in the absence of natural predators, they have increased their population dramatically to become a pest of considerable importance. Scanty information is available on its introduction to Mauritius but it is quite possible that Mauritius was exposed to the Indian house crow (IHC) ever since ships sailed between southern Asia and Mauritius. It is reported that British ships carrying rice from Burma berthing off at Port Louis brought a few IHC’s which flew inland. (Captain Betuel, pers. comm). Presently the crow bird population has increased in numbers and is reported to be a nuisance in several areas in Mauritius. It has major negative impact on the native avian species depredating newly hatched eggs and offsprings and will affect animal farming activities particularly poultry. Their incessant long sharp enunciated caws are also very disturbing. In the past several control strategies were tried against these birds (use of cages, shooting and poison application) but all were of little avail. Presently a new chemical known as Starlicide was used incorporated with meat during this study to control / eradicate the population of crow in Mauritius.

SOME PHYSICAL AND BIOLOGICAL FEATURES OF INDIAN CROW

The sub species in Mauritius is darker than the nominate race and may be possibly assigned to the Burmese and Western China race, Corvus splendens insolens ( Archer, pers. comm.).
HABITS

The crow is a gregarious species though apparently monogamous once paired off (Archer, pers. obs.). They are also territorial during the day but will congregate at traditional sites to prepare for the night roost. As it gets dark, they take off and head into the trees and their roosts. At dawn they will leave early in the morning to head back to their territories. Rubbish dumps, dry weather watering points, abattoirs, market places, animal farms especially poultry and duck farms, horse stables appear to be non territorial sites which are used communally by crows.

Crows are omnivorous in diets and will eat insects, small vertebrates, bird’s eggs, fledglings, seeds especially corn and in Mauritius they have been reported to suck the blood from the wounds of farm animals (Sauzier, pers. comm). In the coastal areas they have been reported to attack newly born stray dogs puppies. Crow will commensal with man and is highly an efficient survivor.

They are prolific breeders averaging 3-5 eggs per clutch (Archer, 1995) and are probably long lived. Crow will rarely nest on the ground and will build its nest high up in tall trees and branches. The nest is lined with shredded firm twigs, barks, branches and in Mauritius they were observed to use even pieces of metallic fencing materials to strengthen their nests most probably against adverse climatic conditions.

Figure 1 A crow bird.

Figure 2 Crow nest
Negative impact of crows

This introduced avian species has no natural predators in Mauritius and this factor coupled with favourable environmental conditions has contributed to its successful colonization. It has been reported that Indian crow has negative influence on the survival of other indigenous birds species, that is, they affect human health and poultry production.

Predation and displacement of bird species

The predation and displacement of native birds and their fledglings by crows have been well documented and reported (Ryall, 1992a & b). During the project study several observations confirmed the predation of crow on other native or introduced avian species. For example, at the Beau Bassin Prison the presence of crows caused a dramatic decrease in the population of exotic parakeet, which at one time abounded this area. Surveys carried out in the field in selected areas showed complete absence of the Mauritian grey white eye Zosterops mauritianus where IHC existed in high densities, which confirmed possible predation of eggs and fledglings in their nests. This was also confirmed by officer in charge at Belle Vue Agricultural station where crows were reported to attack the young of birds from their nest (Ramdin, pers. comm.).

Potential agricultural pests

The majority of sightings of crow were located where farm activities were carried out especially poultry, beef and ducks. Free range poultry production was affected due to predation on eggs and chicks. IHC’s were also reported to attack calves (Sauzier, pers. comm.) and lambs. At Tombeau Bay local inhabitants reported attack by crows on small chicks at small free ranging poultry fauna. Little information is available on their impact on agricultural crops.

Health risks

It is reported that at least eight species of animal intestinal parasites are known to be harboured by the IHC while disease-causing organisms can also be transmitted passively via their feet, bills and bodies (Archer, Pers. Comm.). These can be passed to humans by the fouling of water supplies and food sources (Ryall and Reid, 1987). In Mauritius crows have been observed at market places, slaughter house, public gardens, coastal beaches and also known to visit reservoirs and available water points for bathing and drinking purposes.

Public nuisance

Their incessant cawing especially at roosting is very harassing to human. They have also been reported to steal foods from market tables and kitchen. They may also cause damage to TV aerials and electrical lines when large numbers alight on either of them resulting in misalignment and possible electrical failures. Many buildings and public gardens and roadways have been badly soiled by their droppings. In Mauritius this was observed in and around Jardin de la Compagnie. Some reports have also indicated that humans have been prone to crow attack in areas like Tombeau Bay and Pointe aux Sables.

Chemical DRC 1339 and its mode of action

DRC 1339 or Starlicide is made up of a 98% concentrate of the chemical 3-chloro-methylbenzene-hydrochloride. It has been produced by The United States Department of Agriculture to control the alien European starling and other avian species. Commercially available as a fine white powder the chemical is highly toxic to a limited number of bird species including crows. Due to its slow non violent mode of action it is ideal for controlling crows. After ingestion the chemical takes about 30 hours before any poisoning effect is noted. About four hours before death, the birds cease to eat and drink and become listless and non-active. They are seen to perch on branches with feathers ruffled. First they appear to doze but finally they become comatose sometimes with the head under a wing and die as a result of uremic poisoning (damaged kidneys). Poisoned birds are characterized by fluffed out feathers and by tucking their feet inside the lower breast feathers.
They make shrill noises, to show signs of distress, which alert their mates. The chemical does not affect non-target species like dogs, which are common stray animals in Mauritius. It is quickly metabolised to zero poisoning leaving the carcass safe for consumption by any predator.

**PREVIOUS CONTROL METHODS**

Several methods were tried earlier to control the population of crows. The Mauritius Society for the Prevention of Cruelty to Animals used the cage traps. These were placed either on the ground or on well sheltered flat roof where the crows were known to congregate in high numbers. But this attempt did not give conclusive result because of the difficulty in monitoring the cages. Cyclones also destroyed many of the traps placed on roofs of buildings.

Different types of commercial poisons have also been used by other individuals for eradicating crows. The rapid action of the chemical allows the crow to associate the poisoned bait with their deaths and these birds quickly became bait shy. The risk of secondary poisoning and its effect on non-target species such as dogs, cats and other animals were areas of concern.

Shooting was another strategy tried by a few other farm managers but did not prove to be economically viable and safe. There was also a proposal to provide financial incentives to people who would assist in the killing of these birds but this strategy was put down due to the sensitivity of the sites where crows were earmarked. The use of firecrackers in many instances dispersed the crows from their sites, only for a short period and hence this was not was not a viable long-term strategy.

**METHODOLOGY**

**Identification of feeding sites**

The findings of a survey report (Aug.2000) prepared by National Parks and Conservation Service was used as a base material to check for crow sites. The research team was divided into five groups and each group was allocated certain areas for monitoring. These sites were revisited either very early in the morning or rather late in the afternoon when crows are usually known to be most active. Upon reaching the sites, the local people were also questioned and crow’s activities were observed and studied. Excessive droppings and their presence at night with incessant cawing indicated roosting sites. During the day crows were mostly sighted at their feeding places. An intense sensitisation programme using media was put in place to invite the public to provide useful information on the whereabouts of crows. Twenty feeding sites were earmarked and selected for pre baiting.

**Assessing the bird population**

Three counts were carried out before baiting to assess the bird population. The counting was done as follows. Four strategic sites were chosen namely the roofs of Mauritius Commercial Bank headquarters building, Cerne house (2 sites) and Rainbow House in Port Louis. The roofs of these building were ideal sites as the counter could easily spot the birds coming to their roosting site. Four teams each comprising of two officers were organized and each team were posted on each of the four sites. All birds coming from Le Salines and Roche Bois area were counted from the Cerne house, those on Rainbow house counted those birds coming from Tranquebar, and Citadelle while those birds travelling from Le Jardin Plaine Verte and Port Louis market were noted from MCB headquarters.

Bird count was started at 4 pm time at which the crows start to move to their roosting site, and ended at 6.10 pm before dusk. All crow birds flying back to their roosting site were counted visually and recorded. However when some birds retrieved their direction during the flight the count was bracketed and this was readjusted in the final count. e.g. $2+2+3+4+(5)+2+4+6+2+(4)=16$

Two final counts of IHC at the main roosting site were carried out after the control exercise on the 1st and 7th October to check the population of crows.
Pre-baiting of crows at feeding sites

This was carried out early in the morning when the crow is on the look out for food. Initially bread pieces were thrown in open space to attract the birds. Eventually the bread was replaced by either fresh or frozen lean beef. The meat was cut into tiny cubes of 1 cm² size and 400-500 such small cubes were obtained from one kg of meat.

Preparation of poison bait

The chemical Starlicide or DRC 1339 is in the form of a white powder and was recommended at the rate of 40 g per litre of water. As per advice from Archer, only 13 g of the powder per litre of warm water (40° C) was used. The poison was made into a solution by dissolving it first in 250ml of warm water and the solution was made up to 1 litre. The solution was then homogenized by shaking the bottle several times and the liquid was stored in a green bottle to prevent its degradation by light. 100 ml of the liquid poison was used to mix 1 kg of prepared cubes of meat. They were thoroughly mixed so that the meat could absorb a maximum amount of the chemical. The mixed poisoned bait was then placed in black plastic bags ready for use.

Baiting

Everyday baiting was carried out at the same time and using the same procedures as for the pre baiting. At an interval of about 10-15 minutes, handfuls of the poisoned bait were thrown to the crow. This was repeated whenever the bait was depleted, as some crows tend to take more meat than others. Baiting was carried on two consecutive days, as the chemical is known to react after 24 hours. During baiting, gloves and masks were used as precautionary measures against this toxic chemical.

Figure 3  Crow birds taking the poisoned meat bait.

Collection of dead birds and morphometric measurement

Collection of dead birds was done at the roost every morning. Crows were also collected from their feeding sites. The dead carcasses were placed in a black plastic bag. Formaldehyde was sprayed on the carcasses of the dead crows to prevent foul smell. The plastic bags were placed in a big bin for transportation to the incineration site. Thirty crows were randomly chosen, 16 males and 14 females and morph metric measurement were made on body weight, wing length, bill length and development of sexual organs. An electronic balance weighing to the nearest gram was used to measure the body
weight. Wing length was measured by placing the stretched wing on a flat board and a tape to the nearest mm was used. Bill length was taken from the base of the gape to the tip of the upper mandible.

**Figure 4 Dead crow birds**

**Incineration**

All dead birds were taken to Richelieu Livestock Incineration Unit in batches of 200 or more. The plastic bags containing the dead bodies were placed on the iron bars of the incinerator. Old used rubber tyres, dried sugar cane leaves and petrol were used to ease burning. At all times care was taken to ascertain that all carcasses were burnt to ashes and area cleared. The whole operation lasted from 1 to 2 hours depending on weather conditions.

**RESULTS**

**Potential feeding sites for crows**

Twenty feeding sites were earmarked during survey exercise and were used during the control strategy for pre baiting and baiting.

(a) *Bird count*

**Table 1** A typical bird count data.

<table>
<thead>
<tr>
<th>Time (pm)</th>
<th>Cerne House (Post office)</th>
<th>Cerne House (Caudan)</th>
<th>MCB Building</th>
<th>Rainbow House</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.10-4.20</td>
<td>32</td>
<td>6</td>
<td>56</td>
<td>31</td>
</tr>
<tr>
<td>4.20-4.30</td>
<td>46</td>
<td>84</td>
<td>46</td>
<td>24</td>
</tr>
<tr>
<td>4.30-4.40</td>
<td>46</td>
<td>61</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>4.40-4.50</td>
<td>27</td>
<td>20</td>
<td>74</td>
<td>168</td>
</tr>
<tr>
<td>4.50-5.00</td>
<td>74</td>
<td>34</td>
<td>104</td>
<td>107</td>
</tr>
<tr>
<td>5.00-5.10</td>
<td>91</td>
<td>265</td>
<td>83</td>
<td>141</td>
</tr>
<tr>
<td>5.10-5.20</td>
<td>93</td>
<td>316</td>
<td>191</td>
<td>144</td>
</tr>
<tr>
<td>5.20-5.30</td>
<td>84</td>
<td>338</td>
<td>325</td>
<td>380</td>
</tr>
<tr>
<td>5.30-5.40</td>
<td>172</td>
<td>125</td>
<td>289</td>
<td>336</td>
</tr>
<tr>
<td>5.40-5.50</td>
<td>158</td>
<td>200</td>
<td>419</td>
<td>614</td>
</tr>
</tbody>
</table>
Table 1 shows that the flying pattern of these birds to the roost started slowly as from four o’clock and increased considerably as from 5.00 p.m to reach its maximum at 5.20 p.m until the end. The greatest number of birds counted at one interval of 10 minutes was 614.

**Figure 5** Variation in bird count at 10 minutes intervals.

![Graph showing bird count variation](image)

**Figure 5** shows the trend in flying pattern of the birds and the number moving from the different sites to Jardin de la Compagnie, Port Louis. The majority of birds were observed to come from Roche Bois, Baie du Tombeau and Les Salines.

**Bird population data**

Table 2 below shows bird count effected on different dates.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Cerne House (Post office)</th>
<th>CerneHouse (Caudan)</th>
<th>MCB building</th>
<th>Rainbow house</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.7.02</td>
<td>1614</td>
<td>1893</td>
<td>1449</td>
<td>1908</td>
</tr>
<tr>
<td>30.7.02</td>
<td>1752</td>
<td>1547</td>
<td>1396</td>
<td>869</td>
</tr>
<tr>
<td>20.8.02</td>
<td>2089</td>
<td>2700</td>
<td>567</td>
<td>1597</td>
</tr>
<tr>
<td>Mean</td>
<td>1818</td>
<td>2046</td>
<td>1137</td>
<td>1458</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dates</th>
<th>Bird count after control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10.02</td>
<td>531</td>
</tr>
<tr>
<td>7.10.02</td>
<td>683</td>
</tr>
<tr>
<td>Mean</td>
<td>607</td>
</tr>
</tbody>
</table>
Control and/or eradication of Indian crows (*Corvus splendens*) in Mauritius. *M Puttoo and T Archer*

Figure 6 Bird population before and after the control.

![Graph showing bird population before and after control exercise](image)

A decrease in number of birds in all the four sites was noted after the control exercise.

Figure 7 Status of crow population

![Graph showing crow population status](image)
Figures 6 & 7 show a marked decrease in the population of crows from about 6,800 to 1,300 after the control exercise was completed.

Table 3 Some morphometric data of crow birds

<table>
<thead>
<tr>
<th>Morphometry</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average body weight (g)</td>
<td>275.4 ± 17.7</td>
<td>249 ± 11.3</td>
</tr>
<tr>
<td>Min</td>
<td>125</td>
<td>200</td>
</tr>
<tr>
<td>Max</td>
<td>335</td>
<td>315</td>
</tr>
<tr>
<td>Bill length (cm)</td>
<td>43.18 ± 0.97</td>
<td>39.1 ± 1.07</td>
</tr>
<tr>
<td>Min</td>
<td>40</td>
<td>36</td>
</tr>
<tr>
<td>Max</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Tail length (cm)</td>
<td>145.6 ± 2.14</td>
<td>143.7 ± 3.48</td>
</tr>
<tr>
<td>Min</td>
<td>135</td>
<td>125</td>
</tr>
<tr>
<td>Max</td>
<td>160</td>
<td>160</td>
</tr>
</tbody>
</table>

There was no significant difference in body weight and wing length between male and female crows (P > 0.05).

Figure 8 Pattern of bill length in male and female crows.

Bill length (Figure 8) was found to be significantly longer in male bird than in female (P < 0.05).

DISCUSSION

Prebaiting

The identification and selection of the feeding sites facilitated the pre baiting exercises whereby crows were habituated in one permanent location. This was an important operation as it facilitated eventual
Control and/or eradication of Indian crows (*Corvus splendens*) in Mauritius. M Puttoo and T Archer

baiting trials, which were important before embarking in the application of the chemical. Pre-baiting activities also lured the crows to selected sites thus allowing targeting of a greater number of crows during the baiting with the poison. This is important as crows are known to be suspicious and can easily develop bait shy characteristics. Earlier trials with other chemicals have confirmed this behaviour of crows.

**Bird count**

The bird count strategy proposed by the consultant was carried out by visual recording because similar methods for counting crows have been tried in some African countries. The selection of roofs of tall buildings for counting is also an advantage as the crows could be monitored from a given direction. In the local context, this exercise was rendered easier because the major local populations of crows were observed to return every afternoon to one specific roosting site.

**Ideal bait material**

The best bait material for the control of crows is lean beef meat because crows relished the meat. The lean meat being fat-free could be easily cut in suitable size for feeding the birds. The cubical form of the meat pieces also provides a large surface area for maximum absorption of the chemical.

**Dosage rate of DRC1339**

Despite the recommended rate of 40g/litre, Archer reported that 13g/litre was ideal for controlling crow as it has given good control result. Also at this rate it took almost 30 hours for the poison to kill the birds. This period of time between application of bait and collection of dead birds allowed maximum baiting to be effected at each site before the birds started showing sign of distress. In the control of crows, this is an important factor as crows are known to be suspicious and the more time they take before being affected by the poison is an advantage as it prevents them from developing bait shy behaviour. DRC is also a very costly chemical and reducing its dosage rate may be a financial advantage in the control strategy.

**Morphometric data**

Regarding the morphometric data on body weight, bill length, tail length more samples should be selected to confirm these findings. Archer (1995) reported similar morphometric data on body weight and tail length of crow birds in Eastern Africa. The development of the sexual organs in both males and females is a sign that these birds were soon entering their breeding cycle. This was confirmed as crows were observed to start their nest building in several sites. In a study effected on 651 tagged individuals McGowan confirmed that crows are cooperative breeders and apparently mate for life. Observation carried out during bird count in Mauritius showed that crow would fly in pairs to their roosting sites. However, more observations and studies under local conditions are needed in these areas to confirm the breeding characteristics of crows.

**Crow nest**

The materials used in the construction of their nests were different from those used by native and introduced birds. It also showed an indication of the precautionary measures taken by these birds to adverse weather conditions like cyclones which prevail during their breeding season. Mc Gowan, Curator of Ornithology and Mammalogy at Cornell Vertebrate collection reported that crows rebuild their nests every year at different sites from previous locations. Mc Gowan also confirmed that crows has an established home territory where they would congregate to feed, build their nests and raise their young. In Mauritius this territorial habits were confirmed, as crows were located in more than 20 sites of different biogeographical regions.

**Impact of cyclone as a control factor for crow**

One of the possible factors, which may have contributed to check the population of crows, is the prevalence of cyclones. These calamities strike Mauritius commonly between November to February which coincides with the breeding season of crows. It is predicted that the absence of cyclones during


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Control and/or eradication of Indian crows (corvus splendens) in Mauritius. M Puttoo and T Archer

the past previous years may have contributed to boost the population of crows in Mauritius (Archer, Pers. Comm.)

CONCLUSION

DRC 1339 is an effective chemical, which can be safely and humanely used in the control of crows. The control strategy applied during this study was successful as confirmed by the drastic reduction in the crow population.

RECOMMENDATIONS

- Studies should be carried out to monitor the breeding cycle of the birds so as to monitor their nesting habits.
- Regular monitoring of the population of crows (every 2 or 3 times a year) is recommended for Mauritius.
- The behaviour and reaction of the other native birds in areas where crow populations have been reduced should be monitored.
- The effect of cyclones in Mauritius which coincide with the breeding cycle of crows should be studied in more depth to see their effects on the young and the nests.

ACKNOWLEDGEMENTS

I would like to thank the following persons who have contributed in the preparation of this paper. Mr Y. Mungroo, Director National Parks and Conservation Service, Mr T. Archer, Consultant to crow project, Mr V Nundlaull, Technical Officer and staff of National Parks and Conservation Service who were involved in the project, Mrs. A Melor, Director of Eradicators Ltd including her technical team, and Miss S.A.Vytelingum (Trainee attached at NPCS).

REFERENCES


ABSTRACT

Nine trials have been planted in three agro-climatic zones to evaluate the growth and palm cabbage yield of eight species of palms. In January 2002, following cyclone Dina, the damage was rated on three-year old plants at three sites, on two-year old ones at three sites and on one-year old ones at three sites. Three forms of adverse effects of cyclone - leaf damage, root lodging and stem breakage - were rated, each on a five-point scale.

Two species of local palms - Dictyosperma album var conjugatum (palmiste blanc de l’Ile Ronde) and Acanthophoenix rubra (palmiste piquant) did not show leaf damage. Four species - Cocos nucifera (coconut), D album var album (palmiste blanc de Maurice), Roystonea oleracea (royal palm) and Euterpe oleracea (açai) showed minimal damage to mild leaf tearing. In the last two species, Bactris gasipaes (pejibaye) and Veitchia montgomeryana (palmier de pâques), the damage to the leaves was severe and consisted of tearing of leaflets and some twisting of petioles, but no leaf breakage was observed.

Root lodging (verse) was not observed on four species: the two palmistes blancs, palmiste piquant and açai. In the last two species, this was possibly because the plants were still very small. In pejibaye, root lodging varied from minimal at some sites to severe at others, and the extent of lodging was not related to the stage of development. The last three species - coconut, royal palm and palmier de pâques - lodged severely at several sites. In the case of coconut, this may have been due to shallow planting.

Stem breakage was not observed on five species. A few broken stems were seen in palmier de pâques at one site and in royal palm at two sites. Only in pejibaye, the fastest-growing species, were there many broken stems, up to 30% at two sites. The damage was more severe at these sites probably because the plants were tallest and more exposed. At one site, some of the broken stems had in fact reached the harvest stage. This species may need the protection of windbreaks. At all sites, all species recuperated within three months.

Keywords: palm cabbage, leaf tearing, root lodging, stem breakage

INTRODUCTION

Palms have been grown for their edible heart or cabbage for a long time in Mauritius. At the moment there are about 250 hectares under cultivation, most of them on marginal lands on sugar estates. In the early 1980s, attempts were made to export palm hearts to Réunion and South Africa, but currently, production is insufficient for the domestic market. Producers in the Groupement Palmiste are attempting to increase production and improve cultivation methods and marketing.

The heart of many palm species is consumed around the world, but not all palms have edible hearts. The most well-known species with edible hearts are the coconut, the oil palm and the pejibaye (Bactris gasipaes) but only the latter is cultivated for its heart. In Mauritius, only a single endemic species, the hurricane palm (Dictyosperma album) is cultivated. This species is variable and three sub-species are recognized. They are var album (palmiste blanc de Maurice) which is the main species grown, var conjugatum (palmiste blanc de l’Ile Ronde) which is very rarely grown, and var aureum (palmiste blanc de Rodrigues) which is not cultivated (Bosser et al. 1984).

D. album is also grown on a limited scale in Réunion but the main cultivated species there is Acanthophoenix rubra, known as palmiste rouge in Réunion and as palmiste piquant in Mauritius. A. rubra is endemic to Réunion and Mauritius and is not grown commercially here.
The heart of *D. album* var *album* is reckoned by gastronomists to be excellent even though it oxidises readily. However, the species is susceptible to a major insect pest, *Brontispa limbata*, and has a rather slow growth. On the marginal lands where it is planted, it takes five to seven years to produce a harvestable heart. In contrast, several species are known to be ready for harvest in two to two and half years, for instance the pejibaye (*Bactris gasipaes*) in commercial plantations in Latin America (Clement et al. 1993).

In 1998, the Groupement Palmiste signed a research contract with MSIRI on the importation and evaluation of species with faster growth. The project has been implemented since 1999. The growth of seven new varieties and one control, *D. album* var *album*, is being followed in nine trials in different agroclimatic zones.

When in January 2002 cyclone Dina passed close to Mauritius, there was an opportunity to assess the reaction of the eight species in the trials to the cyclonic conditions. In countries such as Mauritius situated in the cyclonic belt, cyclones have always to be reckoned with since they cause much damage to agriculture. The risks of damage are particularly high on perennials such as palms which are exposed to cyclones over several seasons. However, these risks have not yet been quantified on palms anywhere in the world. The reaction of most of the palm species in the trials is therefore being reported for the first time.

**MATERIALS AND METHODS**

Very intense tropical cyclone Dina passed at its closest point to Mauritius – 50 km to the North at point 19.5° South and 57.6° East – early on 22 January 2002 (Sok-Appadu, 2002). The highest gust recorded was 228 km h⁻¹ and the lowest barometric pressure at sea level was 967 kPa. The country was under the influence of cyclonic winds in excess of 125 km h⁻¹ for 20 hours. Rainfall during the period 20-22 January was highest in the West and Centre and many stations recorded more than 500 mm.

Assessment of cyclone damage was made two to three days after the cyclone on the eight species present in the trials. The species comprise three endemics, *D. album* var *album*, *D. album* var *conjugatum* and *A. rubra*, the well-known coconut (*Cocos nucifera*), two ornamental palms, royal palm (*Roystonea oleracea*) and palmier de pâques (*Veitchia montgomeryana*) and two species originating from Brazil, açai (*Euterpe oleracea*) and pejibaye (*Bactris gasipaes*).

Site conditions and age of the crops on the day of the cyclone are presented in Table 1. With the exception of *D. album* var *conjugatum* which was planted late in some trials, the crops transplanted in 1999 were between 133 and 153 weeks old, those transplanted in 2000 were between 84 and 93 weeks and those transplanted in 2001 were between 43 and 49 weeks. However, because of differential growth rates of the species at the different sites, age may not represent growth stage as adequately as plant height, which is presented in Table 2.

Three forms of damage were rated: leaf tearing and petiole twisting, root lodging, and stem breakage. In each case a damage severity scale of 0 to 4 was used, where 0 meant no visible damage and 4 very severe damage. The scales comprised qualitative and quantitative observations.

**Leaf damage severity scale:**

0. Nil
1. Mild; only tearing of < 30% of leaflets
2. Moderate; tearing of 35-70% of leaflets
3. Severe; tearing of > 75% of leaflets; some (10-15%) twisting of petioles but no breakage
4. Very severe; tearing of > 75% of leaflets; much (> 20%) twisting of petioles; some (> 10%) breakage

**Root lodging severity scale:**

0. Nil
1. Mild; mild lodging (< 15° from vertical axis) on few (< 30%) plants
Cyclone damage to eight species of palms at different growth stages. N Govinden et al.

1. Moderate; mild lodging on 35-50% of plants; moderate lodging (15-30° from vertical axis) on (10-15%) plants
2. Severe; many (55-70%) plants lodged; some (20-50%) showing moderate and a few (10-15%) showing severe (> 30°) lodging
3. Very severe; very many (> 75%) plants lodged; many (> 30%) showing severe lodging

Stem breakage severity scale:
0. Nil
1. Mild; few (< 5%) broken above growing point
2. Moderate; some (10-15%) broken above growing point
3. Severe; several (20-30%) broken above and few (< 5%) broken below growing point
4. Very severe; many (> 35%) broken above; some (10% +) broken below growing point

Table 1  Site conditions and age of crops on day of cyclone

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DR-BC</td>
<td>Sans Souci</td>
<td>Bois Chéri</td>
</tr>
<tr>
<td>Date planted</td>
<td>9-Feb</td>
<td>24-Feb</td>
<td>2-Jul</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>110</td>
<td>280</td>
<td>480</td>
</tr>
<tr>
<td>Mean air temp. (°C)</td>
<td>22.9</td>
<td>21.5</td>
<td>20.1</td>
</tr>
<tr>
<td>Mean annual rainfall (mm)</td>
<td>2,500</td>
<td>3,700</td>
<td>3,800</td>
</tr>
<tr>
<td>Climatic zone</td>
<td>Superhumid</td>
<td>Humid</td>
<td>Super humid</td>
</tr>
<tr>
<td>Age of crop (weeks)</td>
<td>153</td>
<td>150</td>
<td>133</td>
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Table 2  Plant height of different palm species on day of cyclone

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DR-BC</td>
<td>B Chéri</td>
<td>Britannia</td>
</tr>
<tr>
<td>D. album. album</td>
<td>282</td>
<td>185</td>
<td>171</td>
</tr>
<tr>
<td>D. album. conjugatum</td>
<td>228</td>
<td>130</td>
<td>41**</td>
</tr>
<tr>
<td>A. rubra</td>
<td>NP</td>
<td>NP</td>
<td>70</td>
</tr>
<tr>
<td>Coconut</td>
<td>500</td>
<td>195</td>
<td>172</td>
</tr>
<tr>
<td>Royal palm</td>
<td>NP</td>
<td>280</td>
<td>207</td>
</tr>
<tr>
<td>V. montgomeryana</td>
<td>263</td>
<td>225</td>
<td>206</td>
</tr>
<tr>
<td>Açai</td>
<td>215</td>
<td>65</td>
<td>80</td>
</tr>
<tr>
<td>Pejibaye</td>
<td>NP</td>
<td>235</td>
<td>287</td>
</tr>
</tbody>
</table>

NP Not planted or already harvested
* Measured from ground surface to tip of last unfolded leaf
** Planted one year later

The species were rated in all the replicates - normally three - in which they were present. The ratings were subjected to analysis of variance directly, as recommended by Little and Hills (1977) since the scales can be considered to have been pre-transformed. Because many species had zero ratings, a constant was first added before the analysis. Means are presented.
RESULTS AND DISCUSSION

Cyclones damage crops in many ways, directly and indirectly. Strong winds tear and break off leaves and branches, and cause roots and stems to lodge or break. Heavy rains wash away seedlings and young plants, cause soils to become waterlogged and, through the softening of the soil, weaken the anchorage of plants.

Cyclone damage depends on many intrinsic and extrinsic factors. The extrinsic ones include duration and speed of sustained winds and of maximum gusts, which may themselves be influenced by topography and site exposure. They also include amount and intensity of rainfall in relation to soil type and slope. Thus, it is common knowledge that slow-moving cyclones whose wind speeds increase slowly, defoliate many trees whose crowns, therefore, offer less resistance and are less susceptible to breakage and whose stems are less easily toppled over when the maximum gusts occur later. And, as has also been observed regularly, trees growing on loose and sandy soils are more commonly uprooted than those growing on deep and heavy ones. The intrinsic factors include plant height and crown size which determine wind drag; leaf size, shape and fibre content which determine the ease of defoliation; branch and stem size and cellular structure which determine flexibility and ease of breakage; root size, length and structure which determine the ease with which the plants are uprooted. Thus, many more young coconuts were uprooted than old ones and many more tall local varieties were blown down than dwarf ones by cyclone Nigel in Vanuatu (Marty et al. 1986). Similar observations were made by Johnston et al. (1994) following cyclone Gilbert in Jamaica. They noted that selfed Malayan dwarf coconuts were more susceptible to damage that dwarf x tall crosses. Using regression analysis, they showed that canopy size was less important in mortality than plant height and trunk diameter. On loose sandy soils coconuts were more easily uprooted whereas on clayey soils they tended to break (Marty et al. 1986).

In general, palms are less susceptible to cyclone damage than many other species. For instance, Francis and Gillespie (1993) observed after cyclone Hugo in the West Indies that palms were less susceptible than broad leaved species regardless of wind speed. The differential susceptibility of tropical crops is so well-known that Guard and Lander (1999) have used it in their categorisation of cyclones. Thus, in their tropical cyclone scale, a weak tropical storm (maximum sustained wind (msw) 30-40 mph) would cause minor damage to banana, blow leaves from papaya and dead fronds from palms; a minimal typhoon (msw: 74-95 mph) would cause major damage to banana and papaya, twist some palm fronds and blow down small mango trees; a strong typhoon (msw 111-130 mph) would blow off or twist up to 50% of palm fronds and uproot some large mango and breadfruit trees. It would take a devastating typhoon (msw 156-194 mph) to blow down virtually all coconuts.

In the current trials, no leaf damage was observed on palmiste piquant (Table 3), but the species was younger than the others, being present in year 2 (2000) and year 3 (2001) trials only. On palmiste blanc de l'Ile Ronde, damage was absent at seven sites and minimal at the last. Damage on palmiste blanc de Maurice was also absent at five sites, minimal at two sites and moderate at one site - DRBC - where it was taller. These three species are endemic to Mauritius and Réunion, which suggests that their resistance to leaf damage may be a result of their evolution in cyclone-prone areas. Açai also suffered little or no leaf damage, but it was still very short (Table 2). Leaf damage was minimal to moderate on coconut and royal palm and there was no evidence that the older plants were more susceptible. Leaf damage was severe on pejibaye and palmer de pâques with some evidence that the older plants were more susceptible. In pejibaye, the severity of the damage may be related to plant height, this species being one of the tallest at all sites, whereas in palmier de pâques, it may be related to leaf size, the species having the largest leaflets.

Because leaf area is the main determinant of growth, tearing of leaflets and twisting of petioles may have more serious consequences than the ratings of leaf damage suggest. Moreover, species differ in their capacity to produce new leaves and hence recuperate from setbacks to growth following partial or complete defoliation. Growth was being followed in six of the trials and measurements included plant height, bole diameter and number of green leaves. The latter can serve to assess regrowth. At none of the sites was an effect on leaf number detected. For example, at Bois Chéri where leaf damage was severe on pejibaye and palmer de pâques and moderate on coconut and royal palm, the number of green leaves on these species eleven weeks after the cyclone appear to be normal (Figure 1).
Cyclone damage to eight species of palms at different growth stages. N Govinden et al.

### Table 3 Leaf damage in palm species following cyclone Dina

<table>
<thead>
<tr>
<th></th>
<th>Leaf damage rating (*)</th>
<th>(Mean of 3 replicates)</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DR-BC</td>
<td>Sans Souci</td>
<td>Bois Chéri</td>
<td>Bel Ombre</td>
<td>Britannia</td>
</tr>
<tr>
<td><em>D. album. album</em></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>D. album. conjugatum</em></td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>A. rubra</em></td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>0</td>
</tr>
<tr>
<td>Coconut</td>
<td>1.3</td>
<td>1</td>
<td>1.7</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Royal palm</td>
<td>2</td>
<td>0.3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>V. montgomeryana</em></td>
<td>3</td>
<td>NP</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Açai</td>
<td>NP</td>
<td>NP</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pejibaye</td>
<td>NP</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.08</td>
<td>0.1</td>
<td>0.18</td>
<td>0.13</td>
<td>0.18</td>
</tr>
</tbody>
</table>

* Leaf damage rating on a scale of 0 = nil to 4 = very severe
  NP Not planted or already harvested

**Figure 1** Number of green leaves on palm species at Bois Chéri
Likewise, at Belle Vue where leaf damage was severe on pejibaye, palmier de pâques and royal palm, no effect is evident on number of green leaves (Figure 2). This indicates that the setback to growth must have been transient and that, consequently, the adverse effect of the cyclone was minimal.

Root lodging is a very visible but probably inconsequential effect of cyclones. The growing points of many palm species such as the coconut are capable of turning up and resuming vertical growth after the trees have fallen flat. The three endemic species showed no or little root lodging (Table 4), which suggests resistance. Palmiste piquant was quite short, as was açai, another species which was not much affected. The reactions of the other species were very variable and site-specific but not clearly related to age. For instance, in the 1999 trials, coconut lodged severely at DR-BC and Sans Souci but not at Bois Chéri. The difference may be due to shallow planting at the two former sites. The looseness of the soil could be a second determining factor. For instance, in the 2001 trials, royal palm lodged severely at Constance where the site has been restored but not at MT-MD and Savannah on native soil.

Stem breakage is the critical form of cyclone damage. Breakage above the growing point may cause leaf anomalies and stem rot. Breakage below the growing point causes the death of the plant and leads to the total loss of the crop. All the eight species in the three 2001 trials showed no stem breakage, and the data are not reported. Stem breakage was observed in a single species, pejibaye and at some sites only (Table 5). Pejibaye is undoubtedly more susceptible to stem breakage than the other species. This may be because it grows so fast. In fact, at Sans Souci where stem breakage was severe, the species had already reached the harvest stage. Fortunately, pejibaye produces suckers which minimize losses. Nevertheless, there is a need to develop appropriate management practices for this species. A first way to minimize cyclone damage would be to remove all harvestable stems at the beginning of the cyclonic season. A second useful practice in exposed areas is to plant windbreaks.
Table 4 Root lodging in palm species following cyclone Dina

<table>
<thead>
<tr>
<th>Palm species</th>
<th>Root lodging rating (*) (Mean of 3 replicates)</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DR-BC</td>
<td>S Souci</td>
<td>B Chéri</td>
</tr>
<tr>
<td>D. album album</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D. album conjugatum</td>
<td>0</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>A. rubra</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Coconut</td>
<td>4</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Royal palm</td>
<td>2.7</td>
<td>NP</td>
<td>1.2</td>
</tr>
<tr>
<td>V. montgomeryana</td>
<td>1.3</td>
<td>NP</td>
<td>2.8</td>
</tr>
<tr>
<td>Açai</td>
<td>NP</td>
<td>NP</td>
<td>0</td>
</tr>
<tr>
<td>Pejibaye</td>
<td>NP</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Standard error ±</td>
<td>0.24</td>
<td>0.09</td>
<td>0.25</td>
</tr>
</tbody>
</table>

* Root lodging rating on a scale of 0 = nil to 4 = very severe
NP Not planted or already harvested

Table 5 Stem breakage in palm species following cyclone Dina

<table>
<thead>
<tr>
<th>Palm species</th>
<th>Stem breakage rating (*) (Mean of 3 replicates)</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DR-BC</td>
<td>S Souci</td>
</tr>
<tr>
<td>D. album album</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D. album conjugatum</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A. rubra</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Coconut</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>Royal palm</td>
<td>1.3</td>
<td>NP</td>
</tr>
<tr>
<td>V. montgomeryana</td>
<td>0</td>
<td>NP</td>
</tr>
<tr>
<td>Açai</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Pejibaye</td>
<td>NP</td>
<td>3</td>
</tr>
<tr>
<td>Standard error ±</td>
<td>0.23</td>
<td>0.08</td>
</tr>
</tbody>
</table>

* Stem damage rating on a scale of 0 = nil to 4 = very severe
NP Not planted or already harvested

CONCLUSION

Observations made after a single cyclone cannot be expected to give much more than good indications on how different species react. So many factors are involved that the differential reactions cannot be attributed to their underlying causes, especially when wind speeds have not been recorded at the sites themselves. Nevertheless, a number of clear conclusions can be drawn.

Firstly, only one species, the pejibaye, suffered from stem breakage, the worse form of cyclone damage. Fortunately, it produces suckers which can minimize losses. Early harvest and the plantation of windbreaks are two management strategies worth trying on this species.

Secondly, root lodging was quite common in all species except the endemics and the very short àçai. In coconut, there was evidence that root lodging may have been due partly to too shallow planting. But root lodging is not a serious form of damage and may even be considered to be an avoidance mechanism; the stems of plants which lodge do not snap.

Thirdly, leaf damage was moderate to severe in many species. Again, the endemics were much less affected, but no reason can be put forward for their apparent resistance.

Finally, in all species and at all sites, emergence of new leaves and regrowth were rapid and almost no adverse effect of the cyclone could be detected eleven weeks later. This indicates that, although cyclones can be damaging to crops, their effects on the species of palms under study and the risks that they pose to their cultivation here, should not be overestimated.

ACKNOWLEDGEMENTS

We acknowledge the sponsorship of the Groupement Palmiste and the participation of its members in the laying out and management of trials. We thank Dr C Soopramanien, Coordinator of the project. We are grateful to the Director, MSIRI and to the Groupement Palmiste for permission to publish this paper.

REFERENCES


IMPACT OF THE MILK PRODUCTIVITY BONUS SCHEME (1993-1998) ON CALVING INTERVAL

Geerjanand Saraye and Rafik Fakim
Agricultural Research and Extension Unit

ABSTRACT

A series of incentives were introduced in the 1980’s to promote the smallholder dairy sector. The milk productivity bonus scheme was introduced in 1993 and lasted till 1997. The objective was to encourage cowkeepers to increase milk production and the number of calves born per cow through decreasing the calving interval.

This study mainly investigates on the efficacy of the scheme involving 3166 farmers over a period of 5 years. It was found that the average calving interval for calvings less than 450 days was 402 ± 31 days in 1993 and was reduced to 390 ± 32 days in 1998. There was no increase in the percentage of calvings below 450 days during the five years of implementation of the scheme. There was no significant change in the length of the calving interval which is affected also by the reproductive performance of the cows and the management practices of the farmer.

Keywords: incentive, calving interval, reproductive performance, cowkeepers

INTRODUCTION

During the last decade, the Ministry of Agriculture introduced a series of incentives in order to increase milk production at the smallholder level. One of these incentives was the Milk Productivity Bonus Scheme that was introduced in 1993. It had the twin objectives of encouraging dairy smallholders commonly known as cowkeepers to decrease calving interval and increase milk production on their farm.

Under this scheme, the cowkeeper was entitled to 360 kg of cowfeed or 180 kg cottonseed cake at half the subsidized price (the normal price is Rs 4000 and subsidized price Rs 2500 per tonne) once the cow was diagnosed pregnant. It was made available for 2 months before calving and 4 months after calving. The cowkeeper was allowed concentrate feed at a rate of 30 kg every fortnight. This supplementary feeding helped to improve the condition of the pregnant animal and also to maintain her body condition during the early part of lactation. Besides the feed component, the cowkeeper was also eligible for a cash bonus if the calving interval did not exceed 450 days. The cash benefit was dependent on the length of the calving interval. For a calving interval of 365 days the owner would receive Rs 800, whereas for a calving interval of 450 days the amount was only Rs 200. The Division of Veterinary Services of the Ministry of Agriculture was responsible to implement the scheme. However, no scientific study has been done to find out the impact of this scheme on the calving interval.

OBJECTIVE

This study was therefore undertaken to investigate the impact of the scheme on the calving interval at the smallholder level.

Mode of operation of the milk productivity bonus scheme

Most cowkeepers had their cows or heifers bred through artificial insemination while a few did have recourse to natural service. Pregnancy diagnosis was performed by the senior technical assistant
(S.T.A) of the veterinary services three months after artificial insemination. Once an animal was assessed pregnant, the cowkeeper was required to call at the regional veterinary sub-office to fill in an application form for a feed voucher. The S.T.A verified the particulars given by the cowkeeper, forecasted the date of calving and forwarded the application form to the head office of the Division of Veterinary Services for processing. When the cow calved the cowkeeper had to report to the veterinary sub-office to fill in another application form. Again the S.T.A had to visit the cowkeeper for verification of the statement before completing all the particulars. The calving interval was calculated and then the completed application form was sent to the head office for processing and payment of the bonus.

METHODOLOGY

The data used for this study were collected from records kept at the Division of Veterinary Services. A random sample of 50% of farmers who received a cash benefit under the scheme from 1993 to 1998 was taken. The following information was extracted from the data forms: form number, sub-office, cow’s tag number, date of birth, breed, number of animals kept by the farmer, the present and previous calving dates. The total number of calvings for each year from 1993 to 1998 was also obtained. No information was available for calvings exceeding 450 days. The number of calvings exceeding 450 days was obtained by subtracting the total number of calvings less than 450 days from the total number of births.

From the data, the frequency distribution of calvings for intervals 330, 360, 390, 420 and 450 days and the mean calving intervals were calculated. The effects of region (north, east, west, center and south) and breed (Friesian and Creole) on the frequency distribution of calving interval were also determined.

RESULTS

The cattle population in 1993 was 10399 heads out of which 8447 were cows and heifers. There were a total of 13767 calvings for the period 1993-98 and the distribution over the years is given in table 1.

Table 1 Total calvings and average calving interval

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No of farmers who benefited from scheme</td>
<td>651</td>
<td>682</td>
<td>412</td>
<td>380</td>
<td>553</td>
<td>488</td>
<td>3,166</td>
</tr>
<tr>
<td>Total calvings</td>
<td>2,827</td>
<td>2,414</td>
<td>2,234</td>
<td>1,995</td>
<td>2,210</td>
<td>2,087</td>
<td>13,767</td>
</tr>
<tr>
<td>No of calvings by cows</td>
<td>2,000</td>
<td>1,555</td>
<td>1,364</td>
<td>1,143</td>
<td>1,534</td>
<td>1,385</td>
<td>8,981</td>
</tr>
<tr>
<td>Percentage of calvings &lt; 450 days</td>
<td>33</td>
<td>44</td>
<td>30</td>
<td>33</td>
<td>36</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Average calving interval (days)</td>
<td>402</td>
<td>400</td>
<td>398</td>
<td>394</td>
<td>395</td>
<td>390</td>
<td></td>
</tr>
<tr>
<td>SD ±</td>
<td>31</td>
<td>33</td>
<td>34</td>
<td>31</td>
<td>37</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

A total of 3 166 farmers benefited from a cash bonus in the scheme that was valued at Rs 1 877 382. The average calving interval below 450 days varied from 402 ± 31 days in 1993 to 390 ± 32 days in 1998. However, there was no significant change in the length of the calving interval during the 5 years that the scheme was operational.

Figure 1 below shows the number of farmers who benefited from the scheme during the period 1993 to 1998. There was a reduction of 30% in the number of farmers who benefited from a cash bonus under the scheme from 1993 to 1998. It is to be noted however, that there was a decrease in the cattle population from 10 399 heads in 1993 to about 9 000 in 1998.

**Figure 1** Number of farmers who benefited from the scheme (1993 – 1998)

![Bar chart showing the number of farmers who benefited from the scheme from 1993 to 1998.](image)

**Figure 2** shows the percentage of calvings in less than 450 days. There was no significant change in the percentage of calving for calvings less than 450 days. In 1994 the percentage of calvings reached 44%.

**Figure 2** Percentage of calvings in less than 450 days during the period 1993-98

![Bar chart showing the percentage of calvings in less than 450 days from 1993 to 1998.](image)

**Figure 3** shows the percentage frequency of distribution of calving intervals. There was a shift in the peak of frequency of calving from 420 days in 1993 to 390 days in 1998.

**Figure 3** Percentage frequency of distribution of calving intervals during the period 1993-98

![Bar chart showing the percentage frequency of distribution of calving intervals from 1993 to 1998.](image)
Calving interval was not affected significantly by regions and by breeds.

**DISCUSSION**

There was no significant change in the length of the calving interval from 1993 to 1998. It is known that calving intervals depend on many factors, which include the reproductive performance of the cow and the management practices of the farmer. Boodoo et al (1997) showed that smallholder dairy cows resumed ovarian activity, post calving, in 86 ± 38 days. This delay in resumption of ovarian activity is caused by factors like suckling practices, poor nutrition and heat stress. Since the farmers benefited from the concentrate under the scheme it is very likely that the cows were quite well nourished. Yet the data point out that this did not have an effect on the shortening of the calving interval. Boodoo et al (1997) reported similar results when concentrate supplementation was provided free to the farmers. It has also been shown by Boodhoo et al (1998) that farmers either miss oestrus signs or purposely decide not to breed their cows in the first three months after calving. Furthermore a loss of around three months is expected for cows failing to conceive, as the farmer will automatically wait till pregnancy diagnosis before re-inseminating the cow. All these add up to give a long calving interval.

**CONCLUSION**

The data from this study show that the scheme did not decrease the length of the calving interval significantly. Since calving interval affects a cow’s lifetime milk production and the number of calves born it is imperative that the education of the farmer be strengthened to make him aware that he can increase his revenue by reducing the calving interval.
ACKNOWLEDGEMENTS

The authors gratefully acknowledge the collaboration of the Division of Veterinary Services of the Ministry of Agriculture who allowed access to the records and to Mr R. Ramnauth, biometrician for his advice and criticism.

REFERENCES


THE SPIRALLING WHITEFLY, *ALEURODICUS DISPERSUS* (RUSSEL), ITS HOSTS, DISTRIBUTION AND CONTROL PROSPECTS

*B Gungah, SI Seewooruthun and P Nundloll*

Division of Entomology
Ministry of Agriculture, Food Technology & Natural Resources

**ABSTRACT**

*Aleurodicus dispersus* (Homoptera, Aleyrodidae), the spiralling whitefly, was reported for the first time in Mauritius in July 2000. This pest is native to Central America, the Caribbean region and the Pacific islands. It was found in Continental Africa in 1992 when a severe outbreak was reported in Nigeria. From there the pest has steadily spread to other Western African countries. It has been recorded on a wide range of host plants belonging to 27 families and over 100 species elsewhere. Field observations and regular surveys carried out in Mauritius revealed that the pest attacks fruit trees, shade trees, ornamentals, weeds and to a lesser extent vegetable crops. The main hosts include acalypha, poinsettia, guava, frangipani, papaya, Indian almond and banana. The whitefly population is most abundant in coastal areas and other localities of lower elevations with relatively higher temperatures. In regions with altitude over 500 metres, the whitefly population is rather low or negligible. Both adults and nymphal stages caused damage by piercing and sucking sap from foliage resulting on premature dropping of leaves in some plants following heavy infestation. Production of sticky honeydew serves as a substrate for growth of sooty moulds resulting in decreased vigour of the host. Field observations have shown that the spiralling whitefly is becoming a potential threat to the local fruit and vegetable production. In this context, an integrated pest management programme, which includes the use of exotic natural enemies, is envisaged. The most promising natural enemies were found to be the coccinellid predator, *Nephaspis bicolor* (Coleoptera, Coccinellidae) and the aphelinid parasitoid, *Encarsia ? haitiensis* (Hymenoptera, Aphelinidae). These natural enemies will be introduced from the Caribbean and Latin American Regional Centre of CAB International and reared to the first generation under quarantine conditions. They will then be multiplied and released in regions of high infestation of the spiralling whitefly. Eventually releases will be effected islandwide. The impact of the natural enemies will be assessed through monitoring surveys.

**Key words**: Hosts, Damage, natural enemies
THE REDGUM LERP PSYLLID, GLYCASPIS BRIMBLECOMBEI, A NEW PEST OF EUCALYPTUS SP IN MAURITIUS

P Sookar, SI Seewooruthun and D Ramkhelawon

Ministry of Agriculture Food Technology and Natural Resources

ABSTRACT

The redgum lerp psyllid, Glycaspis brimblecombei Moore (Homoptera: Psylloidae; Spondyliaspididae) was first detected at Tamarin in Mauritius on 05 April 2001 on the leaves of Eucalyptus tereticornis. Eucalyptus sp. is the main melliferous plant in Mauritius. If this plant is severely damaged, this may result in a setback to honey production. Furthermore, this plant is used as scaffolding in construction. Studies were carried out as from July 2001 in order to detect the presence of any existing natural enemy and to monitor the psyllid population. Monitoring was done on a monthly basis by direct count of live psyllid on the leaf and by trapping adults with yellow sticky traps in the main eucalyptus plantations. It was observed that the psyllid spread from its detection point to all plantations of E. tereticornis over the island in less than one year. The mean number of live psyllid/leaf/month at Tamarin, Le Morne, Chamarel, Canot, Bell Village, Dauguet, Bras d’Eau and Roches Noires did not exceed 20 during the monitoring period while that for Petite Rivière Noire increased from 15.9 in July 2001 to 103.7 in November 2002. However, leaf drop was not observed in any surveyed locality.

Keywords: Glycaspis brimblecombei, the redgum lerp psyllid, monitoring, yellow sticky trap, natural enemy

INTRODUCTION

The redgum lerp psyllid, Glycaspis brimblecombei Moore (Homoptera: Psylloidae; Spondyliaspididae) was first detected at Tamarin in Mauritius on 05 April 2001 on the leaves of Eucalyptus tereticornis. This psyllid is native to Australia with Eucalyptus sp. as host plants. First records outside Australia were from California, USA in June 1998. http://www.ipm.ucdavis.edu/PMG/PESTNOTES. The insect has been reported to be a potentially serious pest of Eucalyptus sp. outside Australia. Psyllids are plant-juice sucking homopterans in the insect family Psyllidae. During its nymphal or larval stage, this type of psyllid forms a protective cover called a lerp (Plate 1), which makes older nymphs resemble armored scales (Plate 2). However, unlike scale coverings, the lerps are composed mostly of crystallized honeydew and, in this case, resemble small, white, hemispherical caps that grow up to about 3 mm diameter and 3 mm tall. The nymph (Plate 3) underneath each lerp is yellow or brownish and looks similar to a wingless aphid. Older nymphs stay beneath their lerps and generally do not move. Adult lerp psyllids (Plate 4) are slender insects that are about 3 mm long. Their bodies are light green with orangish and yellow blotches and they have clear wings that are usually held rooflike over their abdomen. The adult has relatively long forward projections, genal cones on its head below each eye. Females lay tiny, yellowish, ovoid eggs singly or in scattered groups (Plate 5). Development time from egg to adult varies from several weeks during warm weather to several months during prolonged cool temperatures. Psyllid nymphs and adults feed by sucking plant juices through their strawlike mouthparts. High populations of psyllids secrete copious amounts of honeydew. A blackish sooty mold grows on the honeydew-covered surfaces. High psyllid populations can cause severe leaf drop. http://www.ipm.ucdavis.edu/PMG/PESTNOTES.

Antoine et al. (1990) reported that there are 11 Eucalyptus sp. in the Mascarenes, namely E. grandis W. Hill ex Maiden, E. saligna J.E. Smith, E. deglupta Blume, E. camaldulensis Dehnh., E. citriodora Hook, E. globules Labill., E. chadocalyx F. Muell., E. kirtoniana F. Muell., E. robusta J.E. Smith and E. tereticornis J.E. Smith. Eucalyptus is mainly used as scaffolding in construction. Furthermore, eucalyptus is the main melliferous plant in Mauritius and the most important species include E. tereticornis J.E. Smith, E. robusta J.E. Smith and E. Citriodora Hook (Ramsamy, 1987). If eucalyptus is severely damaged, this may result in a setback to honey production.
The redgum lerp psyllid, *Glycaspis brimblecomei*, a new pest of *Eucalyptus* sp in Mauritius. *P Sookar* et al.

Surveys were carried out in selected sites over the island to determine the presence of any existing natural enemy, to follow the spread of the pest and to monitor its population with yellow sticky traps and by direct insect count on leaves.

<table>
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<tr>
<th>Plate 1</th>
<th>Lerp with psyllid underneath</th>
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<td><img src="image5.png" alt="Plate 5" /></td>
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**MATERIALS AND METHODS**

**Study 1 Examination and breeding of eucalyptus leaf samples infested with the redgum lerp psyllid**

From April 2001 the initial study sites were Tamarin, Petite Rivière Noire and Le Morne. With the spread of the redgum lerp psyllid in nearly all the main plantations of *E. tereticornenis* in the country, Canot, Chamarel, Pétrin, Bell Village, Dauguet, Bras d’Eau and Roches Noires were also included as from February 2002. Eucalyptus leaf samples infested with the redgum lerp psyllid were examined in the field for the presence of any predator. Ten infested leaves from each study site were brought to the laboratory and kept individually in transparent plastic containers for the detection of any parasitoid.
Study 2 Monitoring of the eucalyptus redgum lerp psyllid

Monitoring of the eucalyptus redgum lerp psyllid was carried out by direct counts of the number of psyllids on the leaf, and indirectly by adult trapping with yellow sticky traps. The sites and the period of monitoring were the same as in Study 1. Monitoring of the insect population was done on a monthly basis. Three yellow sticky traps, 14 cm x 21 cm, were placed in the eucalyptus plantation at each study site. The traps were smeared with grease and hung on the plant at a height of about 1.5 m, the minimum distance between two traps being 100 m. The grease was replaced every month when the traps were checked. Direct insect count was done by randomly collecting and examining 20 leaves at a height of about 1.5 m, taken from 10 plants at each study site. The number of live insects on the leaf was noted.

RESULTS

Study 1 Examination and breeding of eucalyptus leaf samples infested with the redgum lerp psyllid

No parasitoid emerged from the breeding of randomly collected leaves infested with the redgum lerp psyllid at the different study sites. Field observation revealed the presence of a general insect predator, *Exochomus laeviusculus* Wse (Family: Coccinellidae) on the leaves. The lady beetle larva was found feeding on the psyllid (Plate 6) while the adults were found on the leaves (Plate 7). Bird species of *Foudia madagascariensis* were found on the infested eucalyptus plants. However, none were observed feeding on the psyllid.

Plate 6 Lady beetle larva, *E. laeviusculus* feeding on the psyllid

Plate 7 Adult *E. laeviusculus* in association with a lerp

Study 2 Monitoring of the eucalyptus redgum lerp psyllid

Figure 1 shows the mean monthly count of redgum lerp psyllid on eucalyptus leaves of *E. tereticornis* at different sites. The mean number of live psyllid/leaf/month at Tamarin, Le Morne, Chamarel, Canot, Bell Village, Dauguet, Bras d’Eau and Roches Noires did not exceed 20 during the monitoring period while that for Petite Rivière Noire increased from 15.9 in July 2001 to 103.7 in November 2002. Error bars around the means Petite Rivière Noire show how variable the leaf counts were. Lower catches of adult redgum lerp psyllid were obtained in November 2002 as compared to those in February 2002 at all the sites with the exception of Chamarel and Bell Village (Figure 2). A relatively higher number of lerps was observed on the eucalyptus leaves in March/April followed by a drop in May/June and this figure rose again in July/August 2002.
The redgum lerp psyllid, *Glycaspis brimblecombei*, a new pest of *Eucalyptus* sp in Mauritius. P Sookar et al.

**Figure 1** Average number of live redgum lerp psyllid per eucalyptus leaf

![Figure 1](image)

**Figure 2** Average number of adult redgum lerp psyllid per yellow sticky trap

![Figure 2](image)
The redgum lerp psyllid, *Glycaspis brimblecombei*, a new pest of *Eucalyptus* sp in Mauritius. P Sookar et al.

**DISCUSSION AND CONCLUSION**

There are eight species of *Eucalyptus* which are known hosts of the redgum lerp psyllid in Australia, namely *E. camaldulensis* (=*E. rostrata*) (river redgum), *E. blakelyi* (Blakely’s redgum), *E. nitens* (shining gum or silver top), *E. tereticornis* (forest redgum), *E. dealbata* (tumbledown redgum), *E. bridgesiana* (apple box), *E. brassiana* (Cape York redgum), and *E. mannifera* (Brittle gum) (Carver, 1987). In California, the psyllid has been recorded on *E. camaldulensis* (=*E. rostrata*), *E. rudis*, *E. globulus*, *E. deiversicolor*, and *E. sideroxylon*. [http://www.ipm.ucdavis.edu/PMG/PESTNOTES](http://www.ipm.ucdavis.edu/PMG/PESTNOTES). In Mauritius, the psyllid was observed on all the locally grown eucalyptus species with the exception of *E. robusta* J.E. Smith. The psyllid count on eucalyptus leaves (Figure 1) and trap catches (Figure 2) were zero at Petrin where *E. robusta* J.E. Smith is the only grown eucalyptus species.

Morgan (1984) reported that the redgum lerp psyllid is multivoltine. Developmental time from egg to adult varies from several weeks during warm weather to several months during prolonged cool temperatures. Under high infestation, the psyllid induces copious growth of sooty mould due to the production of large amounts of honeydew over the surfaces of infested leaves. During the study, it was observed that females of redgum lerp psyllid preferred to lay their eggs on succulent leaves and young shoots, so population increases often followed the production of new plant growth. However, all psyllid life stages occurred on both new and mature foliage. No pupal stage was observed. Young nymphs were observed excreting gelatinous honeydew from their posterior end while older nymphs were concealed underneath their lerps. The production of honeydew resulted in blackened foliage due to sooty mould. At Rivière Noire, it was observed that heavily infested newly developed eucalyptus shoots showed symptoms of deformation (Plate 8). In some cases, lerps that stayed on the leaves for a relatively long period of time produced yellow spots on the leaf surface owing to the absence of sunlight. However, no defoliation was observed in the surveyed eucalyptus plantations despite the fact that the main eucalyptus species in Mauritius is *E. tereticornis*, which is considered as a good host of the psyllid in Australia (Carver, 1987). Furthermore, this plant species was found to be susceptible to the psyllid in California and heavy infestation resulted in defoliation in 1998. However, the trees refoliated in 1999 and were defoliated a second time in 2000. [http://www.ipm.ucdavis.edu/PMG/PESTNOTES](http://www.ipm.ucdavis.edu/PMG/PESTNOTES).

**Plate 8** Higher number of lerps on new foliage with deformation and sooty mould

Intensive studies on the ecology of the redgum lerp psyllid, *G. brimblecombei* have not been carried out (Morgan, 1984). The study of a closely related species, *G. baileyi* in Australia by Moore (1961) indicated that climate may be fairly important with this species as well as with other species of psyllids. There is a relationship between outbreak cycles of psyllids and periods of high rainfall, and higher than normal temperatures were found to cause drastic reductions in populations. Cyclone Dina in Mauritius brought a relatively high rainfall at all the surveyed sites in January 2002 as compared to
The redgum lerp psyllid, *Glycaspis brimblecombei*, a new pest of *Eucalyptus* sp in Mauritius. *P Sookar et al.*

the other months from July 2001 to August 2002 (Anonymous, 2002). It was observed that the number of lerp per eucalyptus leaf was nearly nil in January 2002 (Figure 1). The trap catches at Dauguet, Roches Noires, Bras d’Eau, Chamarel, Le Morne, Tamarin and Canot were lower in January 2002 as compared to those in February 2002.

Its existing natural enemies keep the population of the redgum lerp psyllid in Australia low. Moore (1961) revealed parasitism of the psyllid by chalcidoid wasps to be up to 72% and association of several predators such as *Syritillus viridiceps* Macq. (Syrididae), *Drepanacra* sp. (Hemerobiiidae), *Notochrysa ramburi* Schneider (Chrysopidae), *Rhizobius evansi* Mulsant, *Leis conformis* (Biosd.) (Coccinellidae), spiders namely *Theridion pyramidal* L.Koch, *Deliochus zelivera* (Keyserling), and *Aenea clavatus* Keys) and an encyrtid wasp in the genus *Psyllaephagus*. Pre-existing natural enemies of the redgum lerp psyllid have also been observed in California (http://nature.berkeley.edu/biocon/dahlsten/rglp/nat-enemies.htm). The predators that were observed feeding on the psyllid include Asian lady beetle - *Harmonia axyridis*, minute pirate bug - *Anthocoris nemorales*, two-spotted lady beetle larva - *Adalia bipuncita*, convergent lady beetle larvae - *Hippodamia convergens*, *Chilocorus bipustulatus*, *Coccinella californica*, spiders, insects from the families chrysopidae and hermerobiidae and several bird species, including the chestnut-backed chickadee (*Poeceile rufescens*) and bush tit (*Psalliruras minimus*). However, the existing predators could not keep the psyllid population low. A tiny encyrtid parasitoid wasp, *Psyllaephagus bliteus* was introduced into eucalyptus groves in southern California in 2000 from Australia and promising results have been obtained (http://nature.berkeley.edu/biocon/dahlsten/rglp/nat-enemies.htm). In Mauritius, however, only one lady beetle, *E. laeviusculus* was observed feeding on the psyllid. Studies will be carried out in order to assess the level of predation by this lady beetle and the possibility of augmentative release will be explored.

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http://www.ipm.ucdavis.edu/PMG/PESTNOTES


ERADICATION OF CROWN OF THORNS STARFISH
(ACANTHASTER PLANCI) INFESTATION IN A PATCH REEF IN
THE LAGOON OFF ILE AUX CERFS, MAURITIUS

MS Koonjul, V Mangar and JP Luchmun

ALBION FISHERIES RESEARCH CENTRE

ABSTRACT

The Crown of Thorns (COTs) starfish is a natural predator of live corals. It was observed in unusually high numbers in the patch reef between Ile aux Cerfs and the fringing reef. This paper describes how Crown of Thorns infestation was effectively controlled by injection of dry acid in situ through diving without any adverse effect on the marine environment or other marine organisms.

Keywords: Crown of Thorns starfish, coral polyp, patch reef

INTRODUCTION

Coral reefs in general are threatened by both natural processes and human activities. Whilst, human destruction can be controlled and regulated, the natural causes of reef degradation that include cyclones, coral bleaching and predation by crown of thorns pose a real threat to their survival. However, in case of the latter, timely intervention may alleviate reefs from further destruction. Like other biological infestations (locusts infesting paddy fields), COTs can cause extremely rapid destruction to coral reef ecosystems in a matter of months (N. Fraser et al., 2000).

The crown of thorns starfish (COTs) see Plate 1, Acanthaster planci, is a predator on coral reefs. It belongs to the subclass Asteroida that includes all starfish. The number of arms possessed by an adult specimen may vary from 9 to 21 as depicted in Plate 2. Adult COTs are typically 30-40 cm in diameter and may occasionally grow as large as 70 cm. The COTs have long poisonous spines covering the upper surface, a feature that has given rise to the popular name of ´crown of thorns´. The species is essentially nocturnal. The animal moves with its tube feet at a speed of around 10 cm per minute. It feeds by forcing the stomach out through the mouth and turning it inside out, in a process called eversion. Most COTs prefer fast growing corals such as Acropora spp. The starfish locates itself on the coral polyps, everts its stomach, spreads it over the coral, secretes digestive enzymes onto the coral tissue and then absorbs the digested tissue as it withdraws its stomach. A white skeleton of the coral colony is left called a feeding scar as seen in Plate 3.

The sexes in A.planci are separate and the gametes are shed directly into the water where spawning occurs. The fertilized eggs pass from the egg stage through all the developmental stages to the settling metamorphosing stage after several weeks. Juveniles begin feeding on corals about 18 weeks after metamorphosis and are then about 8 mm in diameter.

A variety of techniques have been used for cleaning up COT infestations. The easiest and cheapest method is the physical removal of COTs when found in shallow waters of the reef and burial ashore in sand just above the high tide level. Utmost care should be taken so that the spines of the COTs, which are poisonous, are not exposed. The other option is to kill the animal by injection of a chemical within the body. Several poisons such as copper sulphate, formalin, liquid ammonia solution and hydrochloric acid have been used. The injection of dry acid or sodium bisulphate is reported to be effective, relatively inexpensive and is harmless to the marine environment and other organisms when properly handled (Lassig, 1995). Dry acid (sodium hydrogen sulphate, 1 hydrate, NaHSO₄·H₂O=138.07, Analar Grade) was used in the eradication of COTs in a patch reef in the lagoon at Ile aux Cerfs.
Materials & Methods

Four trips were made to the COTS hotspot area (Figure 1) using an 8 metre fiberglass boat fitted with a 25HP outboard engine. On site, reconnaissance surveys and injection to COTs was carried out by a team of four divers using SCUBA gear.

During the first reconnaissance trip to the site, GPS positions were noted and the abundance and distribution of COTS was surveyed. This was done using the Line Intercept Transect (LIT) method of the Australian Institute of Marine Sciences (AIMS) by placing transect tapes on the patch corals. The number, size (Plate 4), depth, associated substrate and association in single or groups of COTs found in a belt of 2.5 metres on either side of the transect tape were recorded on underwater slates. Four adult live COT specimens were brought from the site to the laboratory for in vitro tests. In the laboratory, the four COTs were held in live conditions in a concrete tank supplied with running sea water. Two of the COTs were marked and injected with dry acid solution using a plastic hypodermic syringe. The dry acid solution comprised 140 grams of sodium bisulphate dissolved in one litre of sea water. The other two COTs were injected with sea water for control. The total volume of liquid injected per COT was 6 ml at 4-5 different places in the animal. Observations were made after 24 hours following the injection.

Figure 1  Crown of thorns Hotspot

During the second trip, the whole site was literally combed by the divers and all the COTs found were injected with 6 ml of dry acid solution (see Plate 5). The third trip was made 48 hours after the in situ injection of COTs and observations were recorded.
Eradication of crown of thorns starfish (*acanthaster planci*) infestation in a patch reef in the lagoon off ile aux cerfs, Mauritius. MS Koonjul et al.

PLATE 1 Crown of thorns starfish - predator on coral reefs

PLATE 2 An adult COTs possessing 17 arms

PLATE 3 Leftover white skeleton of corals after fresh feeding of COTs

PLATE 4 Measurement of COTs in situ

PLATE 5 Injection of COTs in situ with dry acid
Eradication of crown of thorns starfish (*Acanthaster planci*) infestation in a patch reef in the lagoon off ile aux cerfs, Mauritius. 

**OBSERVATIONS**

For the COTs brought to the laboratory, the two which were injected with dry acid solution were found dead 24 hours following the injection while the other two which received sea water injections remained alive for several weeks, after which they were killed.

In the patch reef, a total of 28 COTs were encountered in the first reconnaissance underwater survey. They were spread on a reef area of about 0.6 km². The patch reef had a mix of substrate comprising corals, algae, sand, and coral rubble. The corals found at the patch reef included acroporids (branching type), montiporids, favids and poritids. The dominant coral species was Acropora spp., whose percentage cover had decreased which may be due to predation by the COTs. A few feeding scars were also observed on the coral colonies and green filamentous algae were seen growing on them. The fish community was dominated by pomacentrids, labroides and acanthurids. It was observed that the abundance of fish species had decreased considerably, which may be due to the decrease in live coral cover.

The COTs were limited to the coral habitat over an extent of 8 864 m² and were in the size range of 24-50 cm in diameter as shown in Figure 2. They were dominant on the substrates in the following order given in Figure 3: live coral (32%), rubble (25%), dead coral (25%) and sand (18%) All the COTs found were solitary in association. The depth at which the COTs were found ranged from 1.5 to 3 metres.

*Figure 2* Size range (cm) of crown of thorns

During the second trip to the site a total of 30 COTs were observed. The increase in number from 28 to 30 may be explained due to the fact that a few COTs remain hidden among the overhanging corals and crevices making it difficult to spot them. The third trip to the site was made 48 hours following the administration of dry acid to the COTs. All the 30 COTS were found dead and shrinking at locations where injections had been administered. No adverse effects to other marine organisms or to the habitat were observed. Four months later, the site was surveyed once more. This time just one COT was observed.
**Figure 3** Frequency of occurrence of COTs with respect to substrate

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**DISCUSSION**

Occurrence of COTs in high numbers in a reef may cause grazing of live corals leading to coral death. In case the COT population is not checked, the whole reef may have vast areas of feeding scars. The COTs may be removed from the reef individually with the help of divers. The long sharp and poisonous spines make handling of the organism difficult. The diver needs to place an iron rod or the blade of a diver’s knife under the body to dislodge it as it firmly holds to the substrate with the tube feet. Use of iron rods or knives and the difficulty in handling the COTs invariably cause breaking of coral heads. These live organisms have to be transported with caution ashore where they are chopped and buried. Chopped parts of the COTs, if left at sea, have the inherent capacity to regenerate just as other echinoderms.

Injection of dry acid to the COTs is a very effective way of eliminating COTs infestations from reefs as shown in this study. The injection is lethal to the organism leaving it dead and its body shrunk just within 48 hours. As the organisms are injected *in situ*, no damage is done to the corals with metal bars or diver’s knives in dislodging the COTs from the coral colonies.

In the reef at Ile aux Cerfs, all the COTs were killed by administering dry acid. The sighting of one COT after four months is attributed to the migration of that animal from the fore reef into the patch reef COT hotspots may thus be controlled with the use of dry acid.

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