PROCEEDINGS

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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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PARTICIPATING INSTITUTIONS

Agricultural Research and Extension Unit (AREU)
Réduit Mauritius
Telephone (230) 464 4876  Fax (230) 464 8809  e-mail areu@bow.intnet.mu

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
Réduit Mauritius
Telephone (230) 454 1018  Fax (230) 464 8749

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)
Albion, Petit Rivière, Mauritius
Telephone (230) 238 4100  Fax (230) 238 4184  e-mail fish@intnet.mu

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)
Réduit Mauritius
Telephone (230) 465 1011  Fax (230) 465 3344  e-mail farc@intnet.mu

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.

Mauritius Sugar Industry Research Institute (MSIRI)
Réduit Mauritius
Telephone (230) 454 1061  Fax (230) 454 1971  e-mail MSIRI@msiri.intnet.mu

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)
Réduit Mauritius
Telephone (230) 454 1041  Fax (230) 454 9642  e-mail mobhai@uom.ac.mu

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-FLHOR,
B.P. 180, 97455 Saint Pierre Cedex, Ile de La Réunion

FOFIFA
BP 1690 Antananarivo Madagascar
email fofifa@dts.mg
TABLE OF CONTENTS 2001

Participating Institutions  v

Foreword  ix

Opening Session

Welcoming address by Alain Noël G.O.S.K, C.B.E Chairman FARC  x
Address by Honourable Pravind Kumar Jugnauth Minister of Agriculture, Food Technology and Natural Resources xi
The B.D. Roy Memorial lecture Keynote Address:
Information technology in agricultural research and extension
Mr Stephen James, Assistant Director, Institute of Arable Crops Research Rothamsted. U.K. xv

Session 1 - Chairman Mr Stephen James

Developing a Geographic Information System(GIS) tool for extension purposes in Mauritius. M Chung Tze Cheong, R Appave and S Jamala  1
Applications of Video image analysis in Agriculture
Y Moutia, M Mangar, M Teeluck, S Sakurdeep, LJC Autrey and S Saumtally  9
A case study in farmer participatory research: The optimum density of tomato
N Govinden, R Rajcumar, B Govrea and K Rummun  23
A three phase approach (OPI) as a research methodology to conduct in-depth investigations on the agricultural activities of small scale farmers G Naidoo  31

Session 2 - Chairman Professor Jagadish Manrakhan

Production of major Colocasia spp in Mauritius: Current status, constraints and opportunities S Jugurnath, S Soomary and P Hanoomanjee  37
Alternate substrates for anthurium production R Nowbuth  45
Crop cycle study in pineapple: Preliminary results RA Bhugaloo  53
A study of the prospects and potential of late production of onion in the region of la Marie
S Seetohul P Hanoomanjee and R Vencatasamy  57
Assessment of the chloride status in the tobacco leaf and some potential sources for the high chloride level Y Cadersa and A Atawoo.  65
Chemosystematics: A new source of evidence for the classification of the endemic flora of Mauritius NR Lai Fang, T Bahorun and G Khittoo  73

Session 3 - Chairman Dr Jean Claude Autrey

Organic agriculture: A myth or reality in the Mauritian context? S Facknath and B Lalljee  81
Potential of olfactory and visual baits for the control of Stomoxys nigra Macq. (Muscidae: Diptera) in Mauritius D Abeeluck, H Ghoorbin and T Rawananshah  91
Lutte Intégrée contre les ravageurs des cultures maraîchères à la Réunion P Ryckewaert et Frédéric Fabre  99
Etude comparée de la biologie du développement chez trois espèces de mouches des fruits (Ceratitis spp Diptera: tephritidæ) nuisibles aux cultures fruitières à la Réunion P Duyck et S Quilici  105

Session 4 - Chairman Mr Jacques Dinan

Handling large populations of sugarcane genotypes at early stages of selection in Mauritius
D Santchurn, H Mungur, L Rivet and K Ramdoyal  115
Elimination of sugar cane yellow leaf virus and sugar cane bacilliform virus by tissue culture Y Parmessur and A Saumtally 127

Oxadiargyl: A new pre-emergence herbicide recommended in potato in Mauritius C Barre, S Seeruttun and A Gaungoo 135

Effect of lime on nutrient content of soils, yield and nutrient content of potato and infestation by leaf miners B Laljee and S Facknath 139

Pilot-Plant investigation of the treatment of synthetic sugar factory waste water using the upflow anaerobic sludge blanket (UASB)process AK Ragen, L Wong Sak Hoe and T Ramjeawon 149

Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative R Voahanginirina 157

Application d’un nouveau procedé de salaison à la valorisation de la venaison A Collignon, F Deumier et P Grimaud 167

Session 5 – Chairman Professor S Boojeedhur

Le suivi de gestion raisonnée des prairies à la Réunion P Thomas, P Grimaud, V Blanfort et A Michon 173

Evaluation of the performance of deer weaners on three different feed supplements H Bheekhee RK Ramnauth, R Lam Sheung Yuen, R Fukim and B Dobe 179

Gestion raisonnée des pâturages dans les élevages de cervidés mauriciens P Grimaud, P Thomas, H Bheekhee et J Sauzier 189

Isolation and identification of infectious bursal disease virus in cell-culture from clinical cases RN Srivastava, D Sibartie, MR Jaumally, R Ramjee and L Arlandoo 195

Session 6 – Chairman Dr D Vencatasamy

Ver à soie et Poisson O Ralambomanana 203

Seasonal distribution of potentially toxic benthic dinoflagellates in the lagoon of Trou aux Biches, Mauritius MD Hurbungs, N Jayabalan and V Chineah 211


Overview of an experimental release method of the silver sea bream in the lagoon at Albion (Petite Riviere Bay) S Khadun, R Hassea, T Shimizu and H Iwamoto 231

Release of marked silver sea bream, Rhabdosargus sarba, in an artificial habitat at the Montagu barachois R Hassea, S Khadun, T Shimizu, H Iwamoto and R Sano 237

POSTERS

Response to urea molasses multi nutrient blocks as a supplement in the diet of goats D Saddul and AA Boodoo 245

Increasing smallholder milk production through concentrate supplementation P Toolsee and AA Boodoo 249

A simple procedure for staining the bones of the silver sea bream Rhabdosargus sarba Hans Bhudoye, Hiromi, T Nakamura, T Shimizu and H Iwamoto 253

The decomposition rate of cattle manure in the two main soil types of the Seychelles K Nancy and J Loustau Lalanne 257

Use of poultry litter for vegetable production S Sunassee 259

Author and Subject Index 265
I feel privileged to present the Proceedings of the 5th Annual Meeting of Agricultural scientists (AMAS) held in May 2001

The AMAS is a continuation, since 1995, of one significant component of the World Bank - supported Agricultural Management and Services Project (AMSP) under be aegis of the Ministry of Agriculture, Food Technology and Natural Resources, namely the dissemination of research information, for the benefit not only of researchers and the innovation actors, but also, and increasingly so, of other stakeholders of the agri-food community.

This activity, in addition to the library / documentation service of the Food and Agricultural Research Council (FARC), being run with invaluable input from the Technical Centre for Agricultural and Rural Cooperation (CTA), conforms to Section (d) of the FARC mission, which is:

“Providing access to, and dissemination of, research-related knowledge and information”

The strategic need for information - and its diffusion - has never been more pressing, constituting as it increasingly does, a key element and mechanism of effective technology transfer, while being sometimes also construed as the single most important determinant of competitive edge. Researchers and the other constituents must keep up-to-date on current research findings and strategic direction. Opportunities should be provided for the different partners to share expertise and debate on a broad range of themes and issues of relevance, and hopefully cooperate in R & D activities.

This forum fulfills such facilitating role presently. The AMAS has also become one of the most extensive reporting and documentation systems for research projects, some of which funded by the FARC, and their output in agriculture, food, forestry and fisheries in Mauritius.

The FARC Research Information System has recently been enhanced by an additional information product and service: compilation of the papers on CD-ROM, and a renovated website that also provides online access to full-text pages of the AMAS proceedings, including an index, in HTML and PDF formats.

It would be appropriate to also highlight the expanding regional dimension of the AMAS, with a welcome participation of neighbouring institutions and countries in the 2001 meeting: CIRAD Réunion, Madagascar and the Seychelles. Also noteworthy is the keynote address by Stephen James, dedicated to the memory of the late and former Director of the Agricultural Services of the Ministry of Agriculture, Food, Technology and Natural Resources, Mr. B. D. Roy, on the very topical subject

‘Information Technology in Agricultural Research and Extension’.

My appreciation finally goes to all the participants, referees, session chairpersons, research institutions and staff of the FARC, who contributed to the success of the 2001 meeting, and not least to the Editorial team for producing a Proceedings now referenced as a publication of international standing.

Jairaj Ramkissoon

Director General
WELCOMING ADDRESS 2001

Alain Noel G.O.S.K., C.B.E.

Chairman, FARC

The Honourable Minister of Agriculture, Food Technology and Natural Resources
Excellencies of the Diplomatic Corps
Members of the National Assembly,
The Vice-Chairman, Moka-Flacq District Council
Mr Stephen James
Members of the Roy Family
The Permanent Secretary,
Ministry of Agriculture, Food Technology and Natural Resources
Vice-chancellor University of Mauritius
Distinguished Guests,
Fellow Scientists
Ladies and Gentlemen

I am pleased to welcome you to this fifth Annual Meeting of Agricultural Scientists (AMAS) organised by the Food and Agricultural Research Council, in collaboration with the University of Mauritius with the support of the Albion Fisheries Research Centre, the Agricultural Research and Extension Unit, the Agricultural Services of the Ministry and the Mauritius Sugar Industry Research Institute.

This gathering continues the tradition of providing a good opportunity for our agricultural scientists to meet one another and share their research results with themselves and the agricultural community at large. We have had another good response to the call for papers. A selection, had nonetheless, to be made. I wish to thank members of the refereing team who have helped us in this evaluation process.

The wish was expressed in previous years to open this meeting to the region and we are singularly pleased this year to have 6 papers from the region to add to the 24 papers from our local scientists which will be presented during our two-day meeting. I hope that we have better response at our next AMAS meeting from other countries in the region. I have to thank the CTA for having sponsored the participation of two scientists.

Permettez moi d’accueillir aussi parmi nous les chercheurs du CIRAD de la Réunion, du FOFIFA et de L’IMFAVET de Madagascar, et des Seychelles.

I have great pleasure in particular to welcome Mr Stephen James, Assistant Director of the Institute of Arable Crops Research, Rothamsted, who will be delivering the keynote address in a moment, and to express our gratitude to him and his Institute for having so kindly accepted our invitation.

A special word of thanks to the Organising Committee which has spared no effort to ensure that this conference will be a success.

Minister, Ladies and Gentlemen,

I thank you for your presence at this meeting, and I now have the 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 2001

Hon. Pravind Kumar Jugnauth
Minister of Agriculture, Food Technology and Natural Resources

Colleague Ministers
Members of the National Assembly
The President, Moka/Flacq District Council
Excellencies Members of the Diplomatic Corps
Chairman of Food and Agricultural Research Council
Ag. Vice Chancellor, University of Mauritius
Mr. Stephen James, Director Institute of Arable Crops
Research, Rothamsted, U.K
Delegates from CIRAD and neighboring Islands
Distinguished Guests & Scientists, Ladies & Gentlemen

It is indeed a great pleasure and privilege for me to be amongst you this morning for the official opening of the Fifth Annual Meeting of Agricultural Scientists. This initiative on the part of Researchers and Scientists in the field of agriculture to meet on a common platform with a view to sharing knowledge, ideas, information and latest developments in their domain, is commendable and the outcome can only be enriching. The tremendous contributions made by such scientists and researchers in today's agricultural sector facing impending threats and challenges, manmade or natural, deserve our congratulations and support.

I am sure the benefits from your interactions during the course of the meeting will pave the way for further consolidation of the regional co-operation, and will help in spinning a regional web for the Agricultural Researchers and Scientists.

Distinguished guests, Ladies and Gentlemen

In Mauritius, agriculture is still a mainstream economic activity, and will continue to play a prominent role despite the diversification of our economic base. In fact, we are currently pulling our efforts together to bring the necessary reforms aiming at an acceleration of the modernisation process in the agricultural sector where new technologies will be increasingly utilised to meet production targets and ensure better resilience in times of harsh climatic conditions.

I am just back from an ACP meeting held in Guyana, where we've been trying to evolve appropriate and pragmatic strategies to live up to the big challenges lying ahead in the international trade front particularly for our Sugar Industry. As you are aware, all the preferential regimes are being dismantled. Negotiations of the reform processes at the level of the WTO are getting tougher. The bargaining powers of developing ACP countries are becoming weaker and weaker in the face of ruthless competition.

There is also emerging, at the international level, another pattern of problems, in the form of pests and diseases, including zoonosis, sometimes explosive with rippling effects at global scale. Consequently, these are compelling many countries to tighten up border controls. The difficulty is more pronounced for fooddeficit countries like Mauritius, dependent as we are on food importation. Definitely such crisis, will seriously limit our access to some food commodities, particularly those of animal origin.

Concurrently, the 21s’ century vision for agriculture itself is changing in the developed countries, with a major thrust for going beyond food, feed and fibre to emerging bio-based industrial products - the BIO ECONOMY - expanding into various bio-based areas: health, energy, chemicals and materials industries. In parallel, given that some of the countries of the EU are currently facing the catastrophe of ‘animal plagues', the pressure for de-intensifying agriculture is increasingly gaining favour. This will focalise the energies of Scientists towards research with a view to find the appropriate remedies.

One tendency observed is the switching from industrial-scale farming towards more sustainable, ethical, environment-friendly agriculture. This will involve fundamental changes in the ways agricultural activities are conducted and will impose major challenges to policymakers worldwide.

In Mauritius, we are fully conscious of such challenges and the Government is currently focusing efforts to boost up research and promote the shift from traditional agricultural methods to modern practices where biotechnology will increasingly take the upper hand. I have the pleasure to announce
that we shall be setting up a National Biotechnology Institute under the aegis of my Ministry to centralise all research activities in the field of biotechnology and provide planters with high-yield and disease-resistant plants. This Institute, I have no doubt, can develop into a major biotechnological centre for the region and Mauritius can become a high-tech nursery for neighbouring countries seeking modern tools to develop and modernise their agriculture.

The need to develop improved, high-yield and climate-resistant varieties is urgently felt in Mauritius presently as agricultural land is being allocated for industrial, tourism and housing purposes. We need to produce more on reduced areas and at competitive prices if we are to succeed in fostering a new era of development for agriculture in our country and live up to the challenges imposed by trade liberalisation.

Everybody will agree that Research is the cornerstone of economic growth and development. One of our commitments to the WTO for an enhanced food security, is precisely "... to promote access to relevant agricultural technology...". We have no alternative than to use the new technologies to overcome our traditional disadvantages of size, isolation and insularity.

While it is my strong belief that Research and Development should take the lead in providing such technologies for the biobased economy of the 21st century through applications technologies such as Biotechnology and IT in particular we should also not forget to pay heed to this emerging mood I referred to earlier the tendency of a conversion to less intensive and greener farming. There is a need, therefore, for an intensification and concentration of research efforts, in the face of these challenges and opportunities. A need for a better output from a more effective research system. We need a new culture to public sector research and extension systems, management and institution-wise; a culture with emphasis on economic efficiency, on clearcut purposes and outcomes; on innovative ideas and technology dissemination; on partnerships including the private sector, to extend the application of new ideas and technologies to producers and other parties.

The expectations from Research and Development are thus becoming higher. The challenge is to expand the Research agenda, without reducing existing priorities, while concurrently being subjected to shrinking budgets. Hence, the greater burden on research administrators and planners to allocate resources to high-priority areas.

The Government has been playing a major role in supporting Agricultural Research. We do realise that Research has a long-term flow needing sustainable funding. Therefore we intend to maintain public investment on the same footing. The creation of FARO and under its umbrella, the AREU, clearly reflects the vision and commitment of Government and policy makers. My humble request is, therefore, not only to reassess your approaches and strategies which should not necessarily be a capital intensive but also to lay out research priorities taking on board stability of production and tolerance of crops to the climatic and environmental stress and changes in the wake of the global warming up.

Ladies and Gentlemen

My Ministry will also continue to provide all possible support needed to Food and Agricultural Research Council to enable it to implement its Strategic Plan 2001 /03 already approved by Government. I do believe that the Council has a major catalytic role, despite the autonomy of the Research Institutions. The University of Mauritius should also continue to extend its support in the Research and Development field. I would choose to highlight some of the key areas that FARC will have to concentrate upon. The foremost thrust would be of co-ordination, and strategic and integrated planning of Agricultural Research and development, with relevance to 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 in the least-cost way, with a minimum of wasteful replication 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 management aspects of research.

But this top-down direction of research programmes through establishment of purposes and guidelines should combine creatively with the parallel approach of internal direction as provided by the Research Agencies themselves. Such synergy can only be beneficial to one and all. We should also enhance national capacities, not only to generate, but also to adapt and transfer knowledge. The coordination between the FARC and the TIDS will thus continue. It will assist in building the base through international cooperation and programmes.
There is therefore a need for a restructured, strengthened and independent FARC, to deliver these objectives with a strengthened in-house institutional capability in such coordination function as well as mechanisms for technology communication, diffusion and enhancement through the development and more extensive use also of the Information and Communications technologies.

The FARC is already involved in terms of producing proceedings, in printed and also CD-ROM versions and shortly through its website. Of course Research and Development alone cannot meet all the challenges facing our agriculture and food sectors. The task also requires enabling policies, and social and institutional factors, and public investments in the needed infrastructure. Many other issues are also arising, that need to be addressed by the Government: issues of regulation, intellectual property, trade, finance, credit, etc. But I can assure you that this Government is committed to the emergence of a Knowledge Society, a society ‘where creating, sharing and using knowledge are key factors in the prosperity and well being of people’.

Distinguished guests and participants, I wish you a very fruitful meeting and assure you of my support and my keen interest in your endeavours and outcomes. May I also extend to all foreign delegates a warm welcome and happy stay in Mauritius.

I have now the pleasure to declare this Conference open.

Thank you.
Minister, Distinguished Guests, Ladies and Gentlemen. Thank you very much for the invitation to address you today. It is indeed a great privilege to do so and I particularly bring you best wishes from all at Rothamsted Experimental Station.

It is especially appropriate that, in the course of this meeting, we are honouring BD Roy, the former Chief Agricultural Officer who passed away in December 1999. In his tribute, Professor Manrakhan stressed BD Roy’s formidable logic and enthusiasm for information from the technical literature. Surely it is just these characteristics that are the ground upon which “Information Technologies” are built. Were he still amongst us today, I expect that BD Roy would be looking at the IT revolution with an enormous enthusiasm tempered by the question how to use it to the greatest benefit of agriculture in Mauritius.

ABSTRACT

The process of transforming data or observations into a coherent, meaningful framework generates information, that is something which can be utilised by the recipient. The technology by which such a transformation is achieved is information technology and in an agricultural context this can be traced back at least as far as Fisher at the beginning of the 1900s. The utilisation of Information Technology (IT) can be considered as having primary (scientific or research) and secondary (technology transfer) stages and is a vital part of agricultural research. Examples of these phases are considered in the context of precision agriculture, decision support systems, the place of the internet, among others.

INTRODUCTION

We tend to think of Information Technology as a modern invention, surrounded as we are by an information explosion based upon amazing computing power on my desk or on my laptop. Like many of you I remember buying by first IBM PC and being the first one in my company to have a hard disc – all 10 Megabytes of it.

Wherever we may be today, we must not forget that we stand on the shoulders of giants. These pioneers are familiar to all of us as the fathers of agricultural research. Perhaps we all have our favourite starting point but I would favour concentrating on 3 great figures:

◊ J-B Boussingault, Bechelbroun, Alsace 1834
◊ J. von Liebig, Giessen 1840
◊ J B Lawes and H Gilbert, Rothamsted 1843

Great men indeed. As you might expect, I am most familiar with the last two on this list and will concentrate on this pair. The vast amount of data that was accumulating from the Classical Experiments, starting from the experiments at Broadbalk in 1843, was after several decades proving to become overwhelming. Even the prodigious minds of Lawes and Gilbert could not hold the complete picture and trends that were emerging when combining natural variation in any one season as well as
that between seasons. Data languishing in experimental notebooks without interpretation are no more than that, they are just data. It is not too much to claim that the appointment of R A Fisher was a significant turning point. With his pioneering “analysis of variance” the time was upon us that vast collections of biological data could be turned into Information (Porter, 1986).

[I must add that as a young man facing examinations at school and University my heart sank if, on entering the examination room I spotted Fisher and Yates Statistical Tables on each desk. Even now I remember the phrase “Using the Statistical Tables supplied analyse the following results and discuss your conclusions”].

Information tends to be an over-used word whose definition is stretched accordingly. Our librarians are, quite reasonably, described as “Information Scientists” who ensure that researchers are well supplied with timely and adequate output from published sources increasingly supplied in electronic format. On the other hand, the computer team is busy developing and implementing the Information Technology strategy. Which brings me to my working definition of “Information Technology”: the means by which we achieve the conversion of data (which does no more than pose the “so-what” question) into information that produces understanding and enlightens the recipient. Understanding is an essential part of the process so we can quickly appreciate that the skills, experience and needs of the intended recipient must influence not only the process of conversion but also its final presentation. Therefore, it can be seen in order to bring benefit to the farmer or other practitioner, information technology must be a least a two-stage process. The first being a primary stage that exposes the data to scrutiny from other scientists with experience in the area, the second being the one that takes the new knowledge into application.

The first stage may be a primary working model from the data. This will help to identify critical gaps in the data collected, inadequacies or sensitivities that need to be tested further, help design new hypotheses and experiments. Clearly, the audience is the researcher and experimentalist. As scientists we are all familiar with such models; they may be formal or informally fashioned, but we all use them. It is worth stressing that even at this stage it is essential to realise that adequate and appropriate training resources need to be available to ensure that those funding the research are getting value for money and that false leads are quickly exposed as such.

Of course this first stage is an iterative process that can be self-perpetuating. There is no problem with this provided that progress is made at each cycle. Similarly, the striving for perfection should not stand in the way of ensuring good knowledge is imparted to farmers and other practitioners as part of the secondary stage. This is the conversion of the scientific conclusions into advice which influences changes in practice that can be put into practice - that is technology transfer. This should be done in such a way that it does not matter how sophisticated the science is behind the concept, but the presentation, or more to the point the interaction tools should effectively convey the best known scientific position to the practitioner. Again this should not be considered as a cheap way of providing extension services, just a tool towards a better way. We are talking about improving management practices through more complete and up to date understanding. Information systems always are a means to an end, never an end in them and they should increase performance of the target, if not their mission has failed.

I need hardly remind this audience but it is worth stressing that a bad information system is worse than nothing. The credibility of the PC message and its very style risk giving a false legitimacy to a flawed information base.

So, in this case we have an example of the general case that is familiar to many. A plant disease is spread by an insect vector and it may be that such a spread can be described by a couple of different generic models and the most appropriate will vary according to circumstances (e.g. Chaussalet et al. 2000). The specialist may be already familiar with the area, will know about how this works and intuitively make allowances. However a “Decision Support System” aimed at the practitioner might have such rules embedded within it and so increase performance of the farmer (e.g. Mann et al. 1996). We will each be able to find examples where such processes can be observed – geographic information systems, video-image analysis, participatory studies analysis, vaccine design, nutrient composition of feedstuffs, automation in animal and plant facilities and so on.

I will devote the rest of my presentation to few examples of which I have some personal experience and each of which reveal the two-stage process that I introduced earlier. Approaching these from different
directions will draw out a number of points about IT in agriculture but there will also be some overlap in concepts in these examples.

**Precision agriculture (PA)**

This is variously known as spatially variable crop production or site specific management and although some observers will choose to bring out distinctions I will treat them as synonymous. This is a highly knowledge and data-input intensive approach to agricultural production. Wagner (1999) suggested that there are two basic approaches, either mapping or real-time:

**Figure 1** Mapping approach to precision agriculture

Figure 1 shows the mapping approach. Historical data is used for as many parameters as possible including output results (harvest in terms of yield and quality) as well as past experience of weed, pests, weather and so on. All this must be provided at a scale suitable for the amount of expected variation and also the ability of the equipment to adjust the input at that scale. There must be crop models that also work at this scale and are able to iterate various hypotheses until an optimal solution is found – this is the stage one of IT that was identified earlier.

The real time methodology depends upon data on weather and conditions of the plant and soil at the time of the cultural activity. It is likely that many of the parameters are not able to be read in this instantaneous way- though the idea of transgenic “reporter” or “smart” plants that indicate their nutritional status in some measurable way is now being seriously contemplated. If these were to be excluded from the harvested crop and so did not enter the food chain such possibilities could become credible options in the next ten years.

Either of Wagner's sub-divisions requires a major investment in Information Technology both in terms of human resources in the scientific developmental stages and in the methods of control of application or cultivation. In effect PA, where practised in an optimal way, will be a combination of both – current information on nutrient status is only relevant with some knowledge of likely rainfall and so leaching risk, and so on. Thus, yield potential of a crop or, more likely, a cultivar and current conditions can be accounted for as well as ecological, economic or legislative constraints.
For PA to be justified, the cost-benefit ratios must be clear. I would suggest a small addition to the suggestion by Plant (2001) of three basic criteria as a starting framework by which these might be judged:

- Significant within field spatial variation
- Causes of the variation are known and measurable
- The information can be combined in a validated scientific model
- The output of the model can be used to influence management practices.

It is likely that the progressive cost reduction normally associated with new IT equipment will bring down the cost of PA application and that its potential will increase as technologies are developed that are aimed at this approach. Its benefit will be most apparent on crops that are in a significant majority in any particular agricultural system – and this would suggest that the sugar crop in Mauritius is just such an example.

The successful adoption of PA is likely to influence the economic and social structure of rural communities across the globe: the importance of different skill sets and tendency to disproportionately benefit larger farm units are two primary such factors. It will also overcome the argument that larger farms are ultimately inefficient and less sustainable because they fail to take account of local but highly significant variation that comes from “grass-roots” knowledge. It is not that this knowledge is not important – quite the contrary, but rather it will become systematised into PA practices.

Increased expectations in terms of traceability and regulatory requirements associated with globalisation may increase the pressure to adopt PA related practices. The problem here may be that the producer will become caught in a positive feed back loop that will not be to his benefit – a sort of regulatory “arms-race”. In such circumstances, it may be necessary to uniquely define the product in some way and find a niche market positioning.

### Policy formulation

Information Technology can play a major role in informing policy development. I will give a couple of different examples of this. In both the UK and in more obvious tourist locations such as Mauritius tourism income can potentially conflict with that from agriculture. At the same time, it may be that the agricultural practice also contributes positively to the features that tourists enjoy. Certainly in the UK tourists wish to visit those places that exist as a consequence of agriculture, but they will resist changes that will benefit the agricultural economy. There can be few parts of the globe that will not, eventually, be affected by this sort of discussion and governments will need policies to deal with the issues. Large scale inventories of natural resources generate enormous data sets, so their effective handling and presentation requires sophisticated knowledge-based, IT management systems.

Some of the best examples of practical decision analysis addressing conflicting needs of this type can be found in forest eco-system management such as that described by Rauscher et al. (2000). These authors showed how to measure and accommodate continuous change in societal perspectives as well as expectations. The system then goes on, within a highly managed productive situation, to develop ways of dealing with aspects such as:

- Need for large scale variety
- Enhanced biodiversity
- Optimal riparian ratio
- Focus on black bears

The more specific case of developing policy and legislative frameworks to deal with pollution potential from nitrogen fertiliser whilst meeting agricultural needs has been developed at Rothamsted (Hesketh et al. 1996). The overall objective is to assist in reducing nitrogen pollution by combining three scientific models:

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Target System</th>
<th>Model Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sundial</td>
<td>soil crop system</td>
<td>dynamic/descriptive</td>
</tr>
<tr>
<td>Ncycle</td>
<td>grazing system</td>
<td>empirical/linear regression</td>
</tr>
<tr>
<td>W.a.t.e.r.</td>
<td>Solute based</td>
<td>dynamic/simulation</td>
</tr>
</tbody>
</table>
This has produced a robust policy model that will allow the assessment of the impact of changes in agricultural practice and policy on nitrate concentration of natural water supplies. Originally used to predict changes at farm level it has been progressively scaled up to be effective at the catchment level. It is able to cope with the wide range of inter-related and complex factors that determine nitrogenous leaching from agricultural land. The primary target user of this is the UK Ministry of Agriculture, Fisheries and Food but it is accompanied by a version for use at farm level to influence management practice and relevant issues are therefore to be found under the discussion on Decision Support Systems.

Indigenous knowledge

This, as well as the rational development of participatory techniques, are areas where I believe there to be enormous unexploited potential for IT applications. The datasets are especially large, diverse and at the moment being, created in a largely piecemeal fashion at different sites across the world. There are rarely systematised in any public IT system, though the less than flattering role of a few of the trans-national pharmaceuticals companies in the exploitation of these knowledge bases inducing an almost paranoid level of fear and resentment is a factor here. My fear is that we will regret this scatter of approaches, which has no common format or philosophy and is likely to thwart any attempt to systematically compare and contrast findings across the world.

**Figure 2** The two track evolution of modern approaches to DSSs

- **Data processing**
  - Sorting, Classifying
- **File management**
  - Integration, File sharing
- **Database management**
  - Relational models
- **SQLs**
  - Ad hoc reports
  - Access by non-technical staff
- **Symbolic models**
  - Linear equations
- **Computer engines**
  - Solving equations
- **Computer models**
  - Program = model
  - “Solved” > “run”
- **Modelling Systems**
  - Model specific software
- **Interactive modelling**
- **Modern DSS**
  - Data + model
  - Dialogue
  - User
Afele (1999) cites examples of indigenous knowledge in Africa and goes on to argue for customised IT systems that are realistic given the infrastructure, social and inherent education standards of the region. Although this may seem a tall order to the purist I have already emphasised that effective IT is about presenting complex models/situations to a relatively naïve audience. Perhaps it is not too much to contemplate the realisation of Afele’s proposal that the impact of IT on sustainable agriculture in Africa would be “the transformation of indigenous agricultural practices into a continuously evolving and learning system based on community-oriented innovative IT systems”.

**Development of decision support systems (DSSS)**

The previous examples are certainly ways in which decisions are being aided by models and IT. This section will discuss the evolution of formal decision support systems and their progression towards an ideal.

The acronym and phrase may be new, but the concept of helping practitioners make decisions is certainly not. In its most literal sense the DSS is the second stage of the simple IT model introduced earlier, but its evolution has followed a somewhat different path. The DSS family is accompanied by expert systems, executive information systems, group decision support systems and so on, but I will use the generic term DSS rather than emphasise the differences.

From a technical perspective today’s’ DSSs are the result of two converging developments (Sprague, 1993); the data processing evolution and the modelling evolution. The first is characterised by the progression from basic data processing, file management, database management and structured query languages. Whilst the second moved from symbolic models, through computer models to truly interactive models.

It is the evolution described in the right hand column of Figure 2 that most of us, as research scientists and agricultural producers, have been using to inform or maybe therefore to “support” our decisions over a number of years. We did not necessarily use the phrase DSS! For instance, the insect survey at centred at Rothamsted and using a network of collecting traps over the mainland of Europe as well as the UK, has been informing farmers of the need, or not, for spraying against aphids since the 1960s and continues to the present day. This is supplemented by the estimate for the first appearance of aphids based upon an equation using winter temperatures as the main input.

This has very effectively been used to reduce the amount of pesticide used, but perhaps more important has been the main tool in the prevention of the development of insecticide resistance. The adequacy of this approach has come under scrutiny as seed coating insecticides are being widely used. The existing model does not have sufficient data by the time drilling/sowing decisions are being made. We are sure that the overuse of precautionary seed dressing is risking the premature appearance of resistance to imidacloprid. Therefore we are anxious to pursue a modification to the current simple model that will influence practice in the future.

Another way of viewing the development of DSSs is to consider a three step model in which the insect survey example is in the second category:

**Figure 3 Three steps in DSS complexity**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic lists of information</td>
<td>Decision tree, single equation steps</td>
<td>Multi-input means, multi-factorial</td>
</tr>
</tbody>
</table>

Today’s DSSs firmly in the category of the third step. Farm production efficiency must be maximised regardless of the economic system in which any organisation is operating. This may be to deal with situations of increasing (global) competition, demands for quality criteria or increasing environmental constraints. The complexity of the decisions is likely to be increased yet further because all of these factors, and more besides, need to be addressed at the same time. There is not necessarily any shortage of information or possible hypotheses on which to base these decisions. The problem might even be
the reverse – how can the wealth of data and sources be combined and the output interpreted by those who need it. That is the classic IT problem.

A new generation of PC users have become accustomed to a common “look and feel” and therefore expect a single system to deliver decision support for all of their farm-based activities/problems whilst at the same time not repeating the entry of common data sets. There should also be a means of capturing remotely generated data such as that coming from weather stations. In Europe, economic unit sizes are increasing rapidly and probably average approximately 1000 ha at present so farm-specific advice could have far-reaching effects. Advances in information technology, especially the options available across the world-wide-web and computing power, are enabling the development of a new generation of DSSs integrating the latest scientific intelligence for use in agriculture.

Decision support systems are backed by complex models derived from a wide variety of different sources and depend upon data covering a range of variables that will influence the value of the decision to the end-user. One such example is DESSAC® (Brooks, 1998) which has been developed through projects jointly supported by the UK Ministry of Agriculture Fisheries and Food and by the farmers levy organisation the Home-Grown Cereals Authority. It is expected to enter its final commercial development phase during 2001.

The heart of DESSAC is the so-called “shell”. This is a generic software environment through which all of the modules interface with each other; with standard farm management software; with external sources of data including internet or dedicated equipment – and with the user. The multi-use modules include encyclopaedia, climate (historic, recent, current or forecast), farm characteristics and records, pesticide data, crop varieties and so on. All of these should be viewable through a standard browser and the whole can be seen as analogous to the common approach seen in something like Microsoft’s Office Suite environment.

To maintain the consistency and compatibility across the modules, a software toolkit is being developed by the DESSAC team and is available to software developers elsewhere in the project. At the same time, criteria have been developed to ensure that other modules conform to standards, meet user needs and are themselves based on properly validated scientific models. The basic design language is Microsoft Visual Basic C++ interacting through Microsoft OLE standards and other conventional facilities such as HTML, ActiveX and Java. The databases are based upon Microsoft Access.

The main components of the Shell include:

- **Database interface** – data description, data entry and reporting, conversion methods;
- **Modelling interface** – compatibility with different modelling principles;
- **Decision processing** – drives the various modules and ensures correct data links;
- **Scenario generator** – exploration and comparison of user driven “what-if” questions;
- **User interface** – top-level re-configurable interface.

Based upon Parker’s premise (1997) that adopting a user-centred design approach is the only way to increase use of DSSs in agriculture, much effort has been utilised to get the user interface right and this requirement has been a central part of the project. So much so that the overall project is led by an expert in this field.

In its current form the DESSAC system is designed to store and organise large amounts of data in different formats which can be analysed and presented to users in a uniform and meaningful way. The system is capable of assessing the consequences of farm management practices such as different spraying dates and doses of different pesticides, changing crop varieties and reporting to users the results in terms of effectiveness and cost. This allows informed choices to be made from the options presented. One of the issues during testing was that novel options were often presented that would not have been common practice. Although sometimes dismissed, further examination by human experts showed these to be real opportunities for improvement.

Each decision support module provides help on a different aspect of crop husbandry by providing analysis of the probable effects of different treatment options. Such analyses are based upon latest
research by leading experts. In addition, each module contains information about the area (e.g., disease symptoms) presented in “book-style”. Thus it becomes possible to:

◊ Inform decisions based on complex datasets not previously accessible by end-users;
◊ Perform multi-faceted analyses that neither farmers nor advisor is normally equipped to do
◊ Examine and compare complex “what if” scenarios;
◊ Provide an audit trail of activities with reference to regulatory constraints.

The DESSAC shell incorporates innovative computing solutions to achieve this challenging goal. However to reach all aspects of the design model shown in Figure 4 a number of major steps are still needed and may need yet further step changes in some of the technological solutions.

Figure 4  Idealised, Multi-faceted Decision Support System

The internet in decision support

In the existing DESSAC product updates are provided from the web to be downloaded on to the customers own PC such that the Shell is always up to date. The consequence of ideal shown in Figure 4 is that only locally relevant data, such as farm history, crop rotations, management accounts, is supported by the users PC. Everything else is held at central server and the bulk of the calculations are done there. This gives the user the option of purchasing – at the time of asking – different qualities of data to suit the particular purpose. This also goes on to link to manufacturers or suppliers of products who may wish the user to be alerted to their product when prompted by a set of decision options.

This begins to overturn the conventional paradigm, but it may be the only way that such sophisticated approaches could become a commercial reality. For instance, there would be a commercial imperative for your product information to be fully described within the system, at the very least, and the advertising option being an option that would attract a cost. Knowing that an individual is growing a particular crop, especially high value more rare crops, may also be of benefit to both trader and grower.
so this system become the entry point to a trading floor as well. In this way the system matures to become a portal – but one which attracts clients dependent upon the quality of its decision support.

A final element that will need to be part of such a scheme is portability and accessibility. The scenario where the advisor has to go back to the office before making suggestions on the best course of action, would be considered retrograde. The position must be one in which the consultant visits the farm and makes on the spot decisions via his WAP ‘phone. It is possible to see ways of abusing such a system, but it may be useful for a state to control a source of advice and have a good knowledge of likely production levels and so plan distribution accordingly. The free access to the sources across the globe are likely to mitigate against widespread abuse. I believe this vision of the future to be a most exciting one and is the way in which the internet resources will actually become a commercial reality delivering real benefit.

More straightforward internet approaches already exist. These may be offering a free service as part of government sponsored technology transfer project. A good example can be seen at http://www3.res.bbsrc.ac.uk/leafspot where the farmer can judge the risk of light leaf spot disease (of oils seed rape) according to region, cultivar, rainfall and what application of fungicide has been applied to date. In this case all of the data rests on the server and it is this which interrogated by the user. As should be the case with good IT the simplicity of the system for the user conceals a number of different models and databases beneath the surface.

Genomics, proteomics and metabolomics

Databases available for browsing have been a feature of the internet for some time and imaginative searching for matches across new sequences have uncovered exciting new genes. The internet and the “omics” sciences have developed side by side and it is the best place to keep up with the general state of the art. (e.g. http://www.nature.com/genomics/human). This is certainly a case where the processing and sharing and the continuous iteration of analyses that was made possible by the current state of information technology was, and is, a pre-requisite for the mapping of the various genomes. Even more important is the next stage; the attribution of functions to the genes and the ways in which these may be modified be it by transgenic means or other interventions.

No discussion of IT could be complete without some mention of this area but I will not attempt any exhaustive treatment. Suffice it to say that no longer is sequence analysis the sole dominion of a small group of interested scientists – the data has become information. This offers opportunities for the analyses to be done outside the traditional research institutions. As a result smaller universities, community colleges and so on from around the globe participate in the world of genomic biology with a comparatively modest admission price, the tools being incredibly powerful, but relatively simple to access and use. With this power comes responsibility – both in the broad ethical sense but also the untrained inquiry could suggest a false trail on which a large number of research pounds, dollars or rupees could be wasted before the erroneous basis is discovered.

CONCLUSION

It is clear that IT has revolutionised our approach to science and will continue to do so for the foreseeable future. This continuous development has brought economic changes: contributed to globalisation of markets and trade; shaken old industrial and business structures and shifted dominance from manufacturing to service industries. It is bound to have social impacts, changing the way that we work and the range of opportunities available to us. Finally, it offers new options for sustainable development. But it also risks creating new divisions in societies – those who have mastered the technology and put it to their use, or at least have the tools to do so, versus those to whom the technology is inaccessible for economic, cultural or other reasons. Such divisions could act at a global as well as a local level.

At a more parochial level, what of the role of research institutes and government support for the continued development of Information Technologies and the raw science that they utilise? The idealised example given in Figure 4 is surely not one that is appropriate for Governments to run – even if they could see administrative opportunities in doing so. Clearly however, the input material (i.e. raw
data and the primary stage scientific models) will typically originate from research projects funded from public sector sources. IT and in particular the DSS is an ideal mechanism by which the new scientific discovery is transferred into practice – after an appropriate period of testing – but the timescale and nature of the interface between public and private sector will need to be re-assessed to capture maximum advantage. I remain convinced that the advantage is considerable for all forms of agriculture across the globe – the prize is so great that we must re-engineer our ways of working in order to gain that goal.

REFERENCES


DEVELOPING A GEOGRAPHIC INFORMATION SYSTEM (GIS) TOOL FOR EXTENSION PURPOSES IN MAURITIUS

M Chung Tze Cheong, R Appave and S Jamala

Mauritius Sugar Industry Research Institute

ABSTRACT

Geographic Information System is essentially a tool to help visualize information in a spatial way. This paper illustrates how extension officers can use GIS to manage individual farmers’ plots, in the large and often remote areas under their responsibility. This application product is a prototype developed, using Visual Basic, map objects and map files generated from ARCInfo. It has a set of menus and buttons with which officers may query the geographic database of the project area. In this instance, data files supplied by the Farmers Service Centre, responsible of farmers fields in St Felix factory area, have been integrated with the map files prepared by MSIRI into a geographic database. Monitoring of yield with respect to the current practice may then be followed and handy documents produced for field visits. Observations from field visits may also be fed into the database so that information accessible to officers as well as decision-makers can be updated. This pilot project is an example applicable to crops other than cane. As illustrated in this study, it allows a dynamic evolution of the system with almost ‘real-time’ feedback at field level. Specific extension goals set for the target farmers could then be grouped geographically viz, irrigation, ripener application and mechanization projects.

Keywords: Geographic Information System, farmers' plots, extension officers, decision-makers

INTRODUCTION

In an effort to increase the sugar cane production of small planters, inclusion of information technology (IT) as part of the extension tool for field officers is becoming a necessity, as extension officers are called upon to cover geographically remote and dispersed areas. Data collection on their part, and their organisation into an appropriate format can therefore be very tedious; consequently the development of a tailored, process-based GIS application will be of great help to the extension officers. As a result of meetings and discussions held with the officers of St. Felix Farmers Service Centre (FSC) on their current needs in data manipulation, it became clear that the extension officers are not all familiar with the computer environment, and do not have much time to learn the GIS software. To develop the application screens, the design of the GIS prototype has therefore been focused on spatial data query, display, and printing and the fact that no prerequisite knowledge of GIS is necessary.

MATERIALS AND METHODS

Data preparation

The source data, which comprised of paper maps and excel files with farmers' data, were provided by the St. Felix FSC for three sub-blocks of St. Felix Factory Area. The spatial data were prepared with the Arc/Info GIS software. Minor changes in the geographic database were then done in the desktop module ARCView, as the map files were linked with descriptive database for shape files creation through a common key id.
Database structure

The databases received as excel files were imported in Microsoft Access 97, and classified according to years and locality sub-blocks. The key id is devised through the concatenation of factory area, locality sub-block and plot number to represent a unique identity for each record (Table 1, Figure 1). The same uniqueness is applicable to the rest of factory areas of the country. A similar key was applied to the map files or shape files.

Table 1 Database structure for farmer’s plots as received from the FSC

<table>
<thead>
<tr>
<th>Column</th>
<th>Item name</th>
<th>width</th>
<th>type</th>
<th>N.dec</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Account</td>
<td>9</td>
<td>C</td>
<td>0</td>
<td>Account number</td>
</tr>
<tr>
<td>10</td>
<td>Name</td>
<td>26</td>
<td>C</td>
<td>0</td>
<td>Planter’s name</td>
</tr>
<tr>
<td>36</td>
<td>LSBP</td>
<td>9</td>
<td>C</td>
<td>0</td>
<td>Field number</td>
</tr>
<tr>
<td>45</td>
<td>TUC</td>
<td>9</td>
<td>N</td>
<td>3</td>
<td>Total area under cane (Ha)</td>
</tr>
<tr>
<td>54</td>
<td>Variety</td>
<td>15</td>
<td>C</td>
<td>0</td>
<td>Cane variety</td>
</tr>
<tr>
<td>69</td>
<td>Noncane</td>
<td>9</td>
<td>C</td>
<td>0</td>
<td>Non-cane</td>
</tr>
<tr>
<td>78</td>
<td>Dateplanted</td>
<td>9</td>
<td>C</td>
<td>0</td>
<td>Date planted</td>
</tr>
<tr>
<td>87</td>
<td>Yrplanted</td>
<td>9</td>
<td>N</td>
<td>0</td>
<td>Year planted</td>
</tr>
<tr>
<td>96</td>
<td>Category</td>
<td>9</td>
<td>N</td>
<td>0</td>
<td>Ratoon</td>
</tr>
<tr>
<td>105</td>
<td>Hardate</td>
<td>9</td>
<td>C</td>
<td>0</td>
<td>Harvest date</td>
</tr>
<tr>
<td>114</td>
<td>Tarea</td>
<td>6</td>
<td>N</td>
<td>3</td>
<td>Total area Ha</td>
</tr>
<tr>
<td>120</td>
<td>Estimated</td>
<td>6</td>
<td>N</td>
<td>0</td>
<td>Estimated yield TCA</td>
</tr>
<tr>
<td>126</td>
<td>Esttch</td>
<td>6</td>
<td>N</td>
<td>2</td>
<td>Estimated yield TCH</td>
</tr>
<tr>
<td>132</td>
<td>Keyid</td>
<td>11</td>
<td>C</td>
<td>0</td>
<td>Unique identity</td>
</tr>
</tbody>
</table>

Figure 1 Database files in Access

Application development environment

The customisation development makes use of the object-oriented approach, in an infrastructure data model, whereby data files like maps and tables, the object libraries of standard office packages like Excel and ACCESS, and of Map Objects, are considered as objects and components of the application development project. The existing functionalities like charting, table display, colour palette of other
software are tapped for graphic display through referencing, and queries performed through the Structured Query Language (SQL), made available in the Visual Basic (VB) development platform, and a multitasked Windows environment. The Visual Basic programming language (Aitken 1998) has been used as a control container to assemble the multiple controls and components for a rapid application development (RAD) (Figure 2)

**Figure 2** Concept of Infrastructure Model used in the application development (adapted from R. Hartman, 1997)

Map objects are an ESRI (Environmental Systems Research Institute 1999) product, consisting of a collection of mapping components (viz., Map objects OCX and other programmable ActiveX automation) for application developers. It provides the possibility to create customised solutions so as to meet the desktop mapping, and GIS needs of common users, through the following facilities:

- Access to a wide range of data formats ranging from standard GIS formats (ARCInfo coverages and ESRI shapefiles) to CAD formats (DXF, DWG, and DGN) to perform spatial queries.
- Display data using classifications (regrouping/categorisation), graduated symbols, and labeling.
- Pan and zoom through multiple map layers.
- Queries features displayed on the map

By means of map objects.OCX and a data connection string, the directory containing the different map files, and their related databases are retrieved and read. (Figure 3)

**List of OCX (Object Controls) used**

- Map control (mo02.ocx): a box in which map layers (shape files) are loaded.
- ADO (ActiveX Data Object): Data control which establishes data connection using ODBC (Open Database connectivity) drivers with the database, and Structured Query Language(SQL) for data query.
- MSHFlexgrid: Hierarchical Flexgrid control which displays the database
- Text boxes: data is bound with the respective database for display results
- Combo boxes: offers possible choice for selection
- Check boxes: Click for display
- Command button: To execute the different functions or events allocated.
- Listbox: To select and display data
RESULTS AND DISCUSSION

Application portability

The whole project, namely the data files (map and tables), program and system files, all ActiveX controls (MapObjects' and VB's), and VB's Data Dynamic Links (*.dll), are bundled into a distributable package such as a setup program. This has been possible through the package and deployment tool of Visual Basic 6.0 version enterprise (Microsoft Corporation). Therefore the application installation does not require additional training or resource investment from the users. It is a sort of 'plug-n-play' tool.

The installation is done through the set up file, which when double clicked, will auto-install the files into their respective folders: system and dynamic link files (*.dll) as well as data files. Further the automatic shortcut installation on the desktop invites the user to start the application program.

Minimum System requirements for this application installation

Operating system: Windows 95 or windows 98
Memory space: 16 MB RAM
Free Hard disk space: 50MB
Microsoft Excel 97
Microsoft Access 97
*Data files: 5 MB
System & program files: 10 MB
Total disk space for setup: 15 MB

* the size may vary with amount of detail collected, and is expected to increase with time.
Application overview

It consists of a user-friendly interface, based on WYSIWYG where the user easily moves across the different screens, with the help of clickable icons, combo boxes, pull down menus for dynamic mapping of the area of interest, and eventual hard prints output.

Screens sequence

Screen 1 - Welcome Form

Screen 2 - Choice of factory area
Screen 3 - Data retrieval from project area locality sub-blocks

Screen 4 - Data analysis
Screen 5 - Spatial query

Advantages of such development

1. Minimum IT investment. The existing desktop environment: Windows and Microsoft Office package is sufficient.
2. A minimum GIS tool is made available, through screen navigation for visual and / or hard prints output. No training is required.
3. No disruption of existing practice. The users may continue with their usual data entry and update with the standard office packages like Excel, or Access, or in simple relational database like Dbase as these components are embedded in the application.
5. Participation of extension officers in their GIS needs.
6. The ease of information retrieval facilitates decision-making at all levels (field officers, management)

Constraints encountered

1. Incomplete descriptive data sets on farmers records caused delays in data matching.
2. Mismatching of field plans with records from the descriptive files.
3. Availability of updated field plans. This implies more ground truthing, and longer time lag to compile and to finalise the spatial data. Conversion of field plan to spatial digital file is still onerous. Sale of updated digital files by the Ministry Of Housing and Lands at a competitive price on the market will give a definite boost to application development of this kind.

Future development

1. Possibility to link different years data with the map files of the same factory area.
2. Possibility of file editing(both map, and data) through customised menus / buttons e.g editing of fields viz., deleting, merging and adding fields as shape files.
3. Extension of the project on a national scale through plug-ins of remaining map files and related data files of all FSCs
4. Privileged Internet access (Brandon 1997) for FSC officers for data analysis.

CONCLUSION

This new paradigm of GIS moving to an open platform, where it is an equal component with other third party software, brings new avenues to common users, and application developers. The GIS products become more affordable, when no more confined to the exclusive environment of professional GIS software, which is usually quite costly, and requires training and skills. This application development is but an example of the infinite technical possibilities of GIS applications, brought about by this breakthrough.

REFERENCES


GLOSSARY

FSC : Farmers’ Service Centre

GIS : Geographic Information System

IT : Information technology

Mo: MapObjects

OCX : ActiveX Components Objects

Shape files are simple, non-topological format for storing the geometric location and attribute information of geographic features.

SQL: Structured Query Language

VB : Visual Basic

APPLICATIONS OF VIDEO IMAGE ANALYSIS IN AGRICULTURE

Y Moutia, M Mangar, M Teeluck, S Sakurdeep, LJC Autrey and S Saumtally
Mauritius Sugar Industry Research Institute

ABSTRACT

The acquisition of a video image analyser (VIA) paved the way to the development of numerous applications in the field of plant pathology as well as in other fields. The equipment was used to develop a reliable method for evaluating the percentage leaf infection by the sugar cane common rust pathogen (Puccinia melanocephala). This had previously been performed by visual examination with a degree of human subjectivity. In the same field, the measurement of uredospores of the rust pathogen allowed its spore size distribution to be rapidly determined with greater accuracy than with the use of a micrometer scale. In plant breeding, pollen grains were measured to test whether size was related to fertility. In irrigation, losses due to wind drift under a centre pivot irrigation system were estimated by measuring the size of droplets collected on water sensitive paper. In sugarcane technology, the measurement of sugar crystals at monthly intervals was carried out for several sugar estates to verify whether their sieves were performing well or required maintenance. For all these applications, the use of the VIA not only proved to be fast and reliable but also more objective.

Keywords: leaf infection, spore size, common rust, pollen grains, irrigation droplets, sugar crystals, video image analysis

INTRODUCTION

Video image analysis

Humans are primarily visual creatures and not all animals depend on their eyes, as we do, for 99% or more of the information received about their surroundings. Image processing is used for two somewhat different purposes (Russ 1995):

a) improving the visual appearance of images to a human viewer
b) preparing images for measurement of the features and structures present

The application of imaging techniques to agriculture and plant science has previously been confined to images obtained through remote-sensing techniques, involving aircraft or satellites, which were then processed and analysed using mainframe computers (Price and Osborne 1980). Since its first developmental stages in the 1970s, computerized image analysis has witnessed a rapid growth and enormous progress (Hader 1992). With the advent of increasingly powerful hardware at affordable prices and the development of ingenious and efficient algorithms, the way was paved for highly specialized and automatic image analysis systems which have found applications in various fields including biology, medicine and industry. Price and Osborne (1980) have reviewed the use of video image analysis (VIA) in agriculture and Lindow and Webb (1981, 1983) reported on the use of VIA in plant disease assessment.

VIA can be described as the acquisition of images or visual information by a sensing device (e.g. a video camera) that are thereafter digitized for computer processing in order to extract and measure features of interest. The analysis is most commonly of morphology (size or shape), intensity, optical density or reflectance, and of the "texture" of the image. Morphological functions specific to the object under study involve the measurement of basic parameters such as area, length, perimeter, breadth, volume and more complex parameters such as aspect ratio and circularity. Moreover, relative positions of objects and counts of objects per unit area are also often required.
In this paper, the use of VIA is compared in terms of accuracy and rapidity to conventional methods for the following applications: quantification of sugar cane leaf area infected by common rust, spore size distribution of the rust pathogen, wind drift losses of sprinklers, pollen fertility assessment and measurement of sugar crystals.

**Quantification of leaf area infected by sugar cane rust**

Sugar cane rust is a foliar fungal disease caused by *Puccinia melanocephala*. The symptoms are rusty-coloured spots on the leaf surface. The disease can affect yield significantly in susceptible varieties (Ricaud and Autrey 1979, Ryan and Egan 1989, Comstock et al. 1992). The development of new varieties includes selection for rust resistance which is measured as percentage leaf area infected. Plant pathologists have used disease assessment keys (James 1971) as reference to carry out this task. This method has several limitations (e.g. subjectivity, a limited number of reference diagrams, provides discrete values) and requires intense and continuous training. In that context, the video image analyser was used to evaluate the diseased leaf area caused by the rust pathogen on sugar cane seedlings.

**Spore size distribution**

The measurement of fungal spores forms an integral part of pathogen identification methodology. A large sample size has to be considered in order to have a fairly good distribution. The traditional method makes use of a scaled eyepiece or graticule. Since the method is tedious and may not be very accurate, the use of VIA was evaluated as an alternative.

**Wind drift losses of sprinkler systems**

Wind drift losses from sprinkler systems can be defined as that part of spray droplets that is carried away by wind outside the sprinkled area. It is important to estimate application losses of sprinkler systems to evaluate their field application efficiencies. This can be done by capturing drift droplets on suitable spray collectors placed at appropriate distances downwind from the sprinkler. The volume of drift passing through a vertical plane can thus be determined and drift losses expressed in terms of the fractions of the flow per unit width of the sprinkler system can be estimated (Teeluck 1994).

Water-sensitive paper (WSP -CIBA-GEIGY 1979, now NOVARTIS) can be used to capture drifting droplets. WSP is widely used in entomology to monitor deposition of aerially applied insecticides (Hill and Inaba 1989). It is a special paper with a water-repellent surface on one side and a dye-coated surface on the other side. The yellow dye turns blue when exposed to aqueous sprays. The resulting permanent stains are in sharp contrast with the yellow background and therefore suited for video image analysis.

**Pollen fertility assessment**

Sugar cane pollen fertility is usually assessed prior to crossing in order to categorise male varieties. A special differential staining technique (Alexander 1969) is used to carry out this assessment. Pollen fertility is estimated from the percentage of fully stained pollen. In the assessment, other pollen features such as size and shape seemed to be linked to fertility and VIA has been used to confirm/infirm these hypotheses.

**Measurement of sugar crystals**

According to Greig et al. (1992), the increase in molasses purity across the C-continuous centrifugals is primarily due to:

- Worn or torn screens causing increased loss of sugar to molasses,
- Excessively fine crystals in the C-massecuite feed, which pass through the screen slot into the molasses and
- Excessive use of wash water or steam, which causes crystal dissolution.

The crystal size distribution of the C-massecuite (a brown viscous material in which sugar crystals are embedded) is therefore of prime importance to the final molasses exhaustion performance. The shape
and the size of a crystal have a direct influence on molasses removal and the effectiveness of the washing operation in the continuous centrifugals.

MATERIALS AND METHODS

The video image analysis system.

The equipment is a Symphony model (Seescan Plc, U.K.) offering true colour image analysis. The basic components of such a system are listed below and shown in Figure 1.

i. A central processing unit with appropriate hardware for true colour image analysis, a Winchester hard disk of 100 Mb, a 720k 3.5” floppy disk drive and a read-write laser drive accommodating 128 Mb cartridge

ii. Two colour monitors

iii. A colour CCD camera with a zoom lens which can also be fitted to a light microscope or binocular

iv. Overhead lights inclined at 45°.

v. An on-line printer and / or video printer for colour images

The software incorporates several subroutines that can be chosen to build a program that will then perform each task in an automated way.

Figure 1 Components of the video image analysis system

Quantification of leaf area infected by sugar cane rust

The experiment consisted of two parts to evaluate:

1. the machine's accuracy
2. the possibility of screening seedlings by using one or more leaves from each plant to estimate overall plant mean infection
Accuracy: VIA estimations v/s Plant Pathologists’ estimations

A range of rust infections was simulated by sticking brown contact paper, cut into small pieces, on a pale green background representing the leaf area. Thirty paper strips measuring 15 x 2 cm² were prepared to represent infection in the range of 0-100%. After initial calibration, the VIA was used to estimate individually the percentage area covered by the mimicked rust spots on each strip. A parallel visual estimation of the percentage "diseased" area was carried out independently by seven persons having different levels of experience of disease evaluation in the field. Each person made two evaluations of the same specimens on different days.

Screening of seedlings

In order to develop the methodology for screening seedlings against rust, progenies from two bi-parental crosses were inoculated (Moutia 1994, Autrey et al. 1996) and leaf samples assessed after four weeks. The parents used in the crosses were:

1. M 555/60 (highly susceptible) x M 1030/71 (highly susceptible)
2. M 695/69 (slightly susceptible) x M 1030/71 (highly susceptible)

Spore size distribution

A uredospore suspension was prepared by vortexing field-collected spores in an Eppendorf tube containing distilled water and a drop of Triton-X that enabled the separation of aggregated spores and facilitated automated analysis. A drop of the suspension was mounted on a slide and the spores observed under the microscope at x250 magnification. After calibration with a micrometer scale, the pre-written program was run. One hundred spores were measured. The parameters recorded were length, breadth and area. The latter was included to improve automated analysis by rejecting non-spore objects of smaller or bigger sizes.

Estimation of wind drift losses of sprinkler systems

Measurements of spray droplets carried out by the traditional graticule (100 µm precision) and binocular method at x25 magnification were compared to those obtained with the VIA. Ten droplets were measured for length and breadth.

WSPs of 26 mm x 76 mm were taped at a height of 3 m on four stands as described by Teeluck (1994). The quantity of spray drift was estimated as follows:

The stains on the WSP were counted to assess the stain density and the diameters of the droplets were measured with a binocular using a scaled eyepiece. A similar task was performed by VIA. The stain diameters were then converted to true droplet diameters by applying the appropriate spread factors as supplied by the manufacturer (CIBA-GEIGY).

Pollen fertility

Pollens grains of eight commercial male varieties (Table 1) were released from anthers (prior to dehiscence) in a drop of Alexander’s stain mounted on a slide and observed at a magnification of x50. Pollen size and Aspect Ratios were determined. Three replicates of 25 pollen per variety were measured for length, breadth and ferret diameter (average of 36 calliper measurements at intervals of 5°). The dimensionless expression called Aspect Ratio was derived by dividing the length of each pollen by its breadth. A value of 1 would represent a perfect circle whereas lower and higher values would indicate an oval shape.
Table 1  Relationship between pollen diameter, aspect ratio and pollen fertility for eight male varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Diameter Mean ± SE µm</th>
<th>Aspect Ratio(L:B) Mean ± SE</th>
<th>Pollen fertility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 245/76</td>
<td>51.6 ± 1.5</td>
<td>1.079 ± 0.008</td>
<td>39.7</td>
</tr>
<tr>
<td>M 881/80</td>
<td>50.2 ± 0.5</td>
<td>1.087 ± 0.007</td>
<td>18.6</td>
</tr>
<tr>
<td>SP 71799</td>
<td>37.6 ± 2.8</td>
<td>1.008 ± 0.006</td>
<td>38.0</td>
</tr>
<tr>
<td>CP 44101</td>
<td>45.1 ± 4.5</td>
<td>1.121 ± 0.025</td>
<td>25.0</td>
</tr>
<tr>
<td>F 149</td>
<td>43.7 ± 1.7</td>
<td>1.170 ± 0.080</td>
<td>13.4</td>
</tr>
<tr>
<td>SP 703370</td>
<td>43.5 ± 2.3</td>
<td>1.108 ± 0.024</td>
<td>19.1</td>
</tr>
<tr>
<td>N 17</td>
<td>39.4 ± 1.2</td>
<td>1.101 ± 0.017</td>
<td>6.6</td>
</tr>
<tr>
<td>M 1182/77</td>
<td>36.8 ± 0.2</td>
<td>1.099 ± 0.072</td>
<td>0</td>
</tr>
</tbody>
</table>

Measurements of sugar crystals

For raw sugar, two methods were compared. Ten crystals were measured by both the conventional method (with an eyepiece graticule fitted in the binocular) and the VIA. For the C-massecuite, 25 g of the sample was weighed in a beaker and covered with glycerol. The mixture was stirred in hot water at 50 °C for 10 min and allowed to stand for 3 h. The deposit was kept and mixed with pure glycerol to separate the crystals for better image analysis. The crystals were mounted on a slide and observed at x50 under a binocular. After calibrating the VIA, a specific program was run to measure the crystals. Breadth and actual area were measured. The mean equivalent diameter (EQ), which is of interest to Process Managers, was derived according to the following formula:

\[ EQ = \sqrt{\frac{(4 \times \text{Area})}{\pi}} \]

Where: Area = Approximate area (length x breadth) or actual area measured by VIA

RESULTS

Accuracy: VIA estimations v/s Plant Pathologists' estimations

Repeated estimations of the same specimens showed the difficulty for plant pathologists to be consistent in their ratings (Table 2).

Differences between readings of the same specimen ranged from 2-30% for some observers (results not shown) as compared to a maximum of 1.4% for the VIA. It was evident that visual assessments were inconsistent in the range 25-80% where the graphical distribution of deviation from the true value was scattered. The VIA, however, had very slight inconsistencies (Figure 2), and the tendency was towards an overestimation in the range 0-50% and an underestimation in the range of 50-100%. Furthermore, a comparison between different observers showed that they were often far from the exact value and also gave very different estimations from each other (Table 2). The VIA was more accurate giving results with more than one decimal place whereas observers could not go below a 1% precision in their estimations.
Development of a methodology for the screening of seedlings against rust

The mean plant infections of crosses M 555/60 x M 1030/71 and M 695/69 x M 1030/71 were in the range 4.25% and 0.14% respectively. The severity of rust on the leaves increased from low in the younger leaves to high in the older leaves. The highest leaf infection recorded was 55.5% on the fifth leaf of a plant of cross M 555/60 x M 1030/71.

Data from the two crosses were combined and 82 seedlings were analysed. The suitability of individual leaves or combination of leaves to represent the plant was determined by calculating the
probability of making the right categorisation/decision given the disease percentage observed on the indicator leaf or leaves. Results (Table 3, Figure 3) revealed that only leaf number 3 and some leaf combinations (leaves 1 and 4 or leaves 2 and 4) were good estimators of plant mean infection.

Table 2 Comparison of simulated percentages to the estimations of two persons and that of the VIA

<table>
<thead>
<tr>
<th>True %</th>
<th>Person 1</th>
<th>Person 2</th>
<th>VIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st estimation</td>
<td>2nd estimation</td>
<td>1st estimation</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>8</td>
<td>5</td>
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<tr>
<td>5</td>
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<td>35</td>
<td>45</td>
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<td>38</td>
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<tr>
<td>45</td>
<td>60</td>
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<td>50</td>
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<td>50</td>
</tr>
<tr>
<td>50</td>
<td>65</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>52</td>
<td>50</td>
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<tr>
<td>60</td>
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<tr>
<td>63</td>
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<td>60</td>
</tr>
<tr>
<td>65</td>
<td>75</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>70</td>
<td>80</td>
<td>75</td>
<td>60</td>
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<td>75</td>
<td>75</td>
<td>70</td>
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<tr>
<td>78</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>82</td>
<td>80</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3 Probabilities of making the right classification / decision and of making error type (1) based on one leaf or a combination of leaves as representative of the plant

<table>
<thead>
<tr>
<th>Leaf / Leaf combination</th>
<th>Probability of making the right classification / decision</th>
<th>Probability of making error type (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf number 3</td>
<td>0.87</td>
<td>0.01</td>
</tr>
<tr>
<td>Mean of leaves 1 &amp; 3</td>
<td>0.82</td>
<td>0.05</td>
</tr>
<tr>
<td>Mean of leaves 1 &amp; 4</td>
<td>0.90</td>
<td>0.01</td>
</tr>
<tr>
<td>Mean of leaves 2 &amp; 4</td>
<td>0.90</td>
<td>0.01</td>
</tr>
<tr>
<td>Mean of leaves 1,2 &amp; 4</td>
<td>0.90</td>
<td>0.03</td>
</tr>
<tr>
<td>Mean of leaves 2,3 &amp; 4</td>
<td>0.87</td>
<td>0.02</td>
</tr>
<tr>
<td>Mean of leaves 1,2,3 &amp; 4</td>
<td>0.94</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Figure 3 Classification of progenies based on a single leaf or combinations of two leaves

Spore size distribution

Frequency distributions were plotted for both length and breadth (Figure 4). The length was found to be $39.06 \pm 0.33 \, \mu m$ (SE) and the breadth $29.14 \pm 0.27 \, \mu m$ (SE). The ranges of spore length and breadth were $31.00 - 47.20 \, \mu m$ and $19.27-34.43 \, \mu m$ respectively.

Estimation of wind drift losses of sprinkler systems

Measurements obtained by both methods (graticule and VIA) are compared in Table 4. Results indicate some important differences (190 \, \mu m) between readings which can partly be explained by the lower precision of the graticule method which was of the order of 100 \, \mu m. However, mean values for length and breadth differed by only 46.4 \, \mu m and 16.67 \, \mu m respectively.

A series of five wind drift tests was attempted under varying wind conditions. The water sensitive papers gave an excellent pattern for visual assessment of the spray droplets. The results are presented in Table 5. The counting of droplets for the determination of droplet density was quickly done. However, measurement of the droplets’ diameters with the binocular and the graticule was slow and very tedious. The VIA method proved accurate and fast. The analyser could additionally separate coalesced droplets before measuring them. This improved the overall results especially on densely covered WSPs.

Pollen fertility

Mean diameter was variable between varieties ranging from $36.8 \pm 0.2 \, \mu m$ in variety M 1182/77 to $51.6 \pm 1.5 \, \mu m$ in variety M 245/76. Aspect ratio was, however, less variable ranging from $1.008 \pm 0.006 \, \mu m$ to $1.170 \pm 0.080 \, \mu m$ in variety SP 71799. Pollen fertility varied from 0% in variety M 1182/77 to 39.7% in variety M 245/76 (Table 1).
Applications of video image analysis in agriculture  Y. Moutia et al.


Figure 4  Frequency distributions of uredospore length and breadth of *Puccinia melanocephala*

![Graph showing frequency distributions](image)

**Table 4** Length and breadth of droplet stains (µm) measured with VIA compared to measurements made with a graticule

<table>
<thead>
<tr>
<th>Measurements with VIA</th>
<th>Measurements with graticule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Breadth</td>
</tr>
<tr>
<td>2 151.0</td>
<td>1 851.0</td>
</tr>
<tr>
<td>860.7</td>
<td>716.8</td>
</tr>
<tr>
<td>920.1</td>
<td>719.4</td>
</tr>
<tr>
<td>1 302.0</td>
<td>986.1</td>
</tr>
<tr>
<td>776.2</td>
<td>587.4</td>
</tr>
<tr>
<td>1 205.0</td>
<td>1 073.0</td>
</tr>
<tr>
<td>1 472.0</td>
<td>961.0</td>
</tr>
<tr>
<td>2 123.0</td>
<td>990.0</td>
</tr>
<tr>
<td>1 483.0</td>
<td>1 257.0</td>
</tr>
<tr>
<td>1 271.0</td>
<td>1 125.0</td>
</tr>
</tbody>
</table>

**Table 5** Wind drift losses from a centre pivot for five wind speeds

<table>
<thead>
<tr>
<th>Wind speed (ms^{-1})</th>
<th>Drift losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 20 m</td>
</tr>
<tr>
<td>1.38</td>
<td>0.21</td>
</tr>
<tr>
<td>2.22</td>
<td>0.20</td>
</tr>
<tr>
<td>5.27</td>
<td>0.91</td>
</tr>
<tr>
<td>6.11</td>
<td>2.15</td>
</tr>
<tr>
<td>6.94</td>
<td>2.89</td>
</tr>
</tbody>
</table>
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Measurement of sugar crystals

For raw sugar crystals (Table 6), the EQs calculated from one-dimensional measurements were not significantly different from those calculated from actual area as measured by VIA.

Table 6 Comparison of raw sugar crystal measurements made with VIA to those made using a graticule

<table>
<thead>
<tr>
<th>Measurements with VIA</th>
<th>Measurements with graticule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured area $mm^2$</td>
<td>D $mm$</td>
</tr>
<tr>
<td>6.557</td>
<td>2.889</td>
</tr>
<tr>
<td>5.090</td>
<td>2.545</td>
</tr>
<tr>
<td>2.450</td>
<td>1.766</td>
</tr>
<tr>
<td>2.238</td>
<td>1.699</td>
</tr>
</tbody>
</table>

For C-massecuite samples from different factories (Table 7), the EQ ranged from 0.169 - 0.304 mm. The maximum coefficient of variation obtained was 29% which is reasonable for such measurements.

Table 7 Measured parameters for C-massecuite samples from 11 sugar factories

<table>
<thead>
<tr>
<th>Factory</th>
<th>Mean breadth $mm$</th>
<th>Mean equivalent diameter $mm$</th>
<th>CV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.280</td>
<td>0.263</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>0.166</td>
<td>0.169</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>0.225</td>
<td>0.238</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>0.257</td>
<td>0.252</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>0.289</td>
<td>0.274</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>0.304</td>
<td>0.304</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>0.251</td>
<td>0.242</td>
<td>17</td>
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<tr>
<td>8</td>
<td>0.272</td>
<td>0.269</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>0.233</td>
<td>0.252</td>
<td>22</td>
</tr>
<tr>
<td>10</td>
<td>0.174</td>
<td>0.173</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>0.190</td>
<td>0.201</td>
<td>21</td>
</tr>
</tbody>
</table>

DISCUSSION

Accuracy: VIA estimations v/s Plant Pathologists’ estimations

The observation that visual assessments are more inconsistent in the 25-80% range corroborates with that of Horsfall and Barratt (1945) who noted that the eye is most capable of estimating accurately in the lower and higher ranges. The VIA was consistent in its errors with a tendency for an overestimation in the 0-50% range and an underestimation in the 50-100% range. Overestimation in the lower half of the scale was due to the presence of relatively more small spots (i.e. many edges) as compared to a larger number of big spots (i.e. few edges) in the upper part of the scale. Indeed, it became gradually more difficult to place the spots on the green paper strips with increasing "disease severity." The VIA proved to be more accurate than human evaluators and results were within 5% of the true value. This finding relates to the Weber-Feckner law or the law of "just noticeable differences"
which stipulates that people recognize a change in a certain value only if the ratio between the change and the initial value is greater than a minimum constant (Ahituv and Neumann 1989).

Development of a methodology for the screening of seedlings against rust

Since it is not practical to analyse all the leaves of a plant by VIA, a method requiring one or two leaf samples per plant is desirable. The classification of progenies into resistance/susceptibility classes forms an integral part of the breeding programme at the MSIRI. In classifying progenies, there are two possible sources of error:

1. classifying susceptible progenies as resistant and
2. classifying resistant progenies as susceptible

Although both are undesirable, the consequence of error (1) is far reaching, involving the possibility of releasing a susceptible variety for commercial planting with the risk of significant losses at field level. Therefore, in the present model it was important to identify the possible indicator leaf/leaves that gave the least probability of error (1) whilst at the same time ensuring good classification and practicality. Leaf number 3 was the most promising candidate with 87% right classification and 1% of error (1). It was also clear from these results that increasing the number of leaves in the sample did not improve the accuracy of classification to a great extent. In practice, measurement by VIA at the seedling stage would have to be supplemented by field observations of the same clones, planted from cuttings, in order to eliminate susceptible ones that could have escaped the initial screening.

Spore size distribution

The measurement of fungal spores is a major aspect of pathogen identification. The automated analysis of one hundred spores was performed in one hour. Such a task would have taken at least three hours had it been done with a graduated eyepiece. Not only did this method save time but it was also less tiring and accuracy was not reduced. The values obtained compared well with those of other workers who probably used a scaled eyepiece although their methods have not been described (Liu 1981).

Estimation of wind drift losses of sprinkler systems

WSPs provide a cheap and an easy means to capture spray droplets from any system as compared to magnesium oxide coated glass slides (Yazar 1984). They have high trapping efficiencies and give an excellent image with a contrasting background for visual assessment. The major difficulty encountered was with the measurement of the droplet sizes. Manual droplet sizing was a very tedious operation. Sizing also required judgement, especially when the droplet stains were more oval than round. This could have probably been an important source of error.

However, it is believed that the accuracy of the method could have been improved if a greater number of paper collectors were used. Indeed, the efficiency of trapping aerial deposits depends on the size, shape and position of the collecting artificial targets (Tu et al. 1986), and the more the morphology of the artificial targets resembles that of the natural substrate, the more efficient is the droplet capture (Spillman 1984). However, in this study, we believe that a greater number of WSP could increase the droplet capture leading to an improvement in the overall results. The problem of droplet sizing can be overcome with the use of VIA. In addition, the equipment offers better precision (1 µm for VIA v/s 100 µm for graticule) and can separate coalescing circular stains, and therefore presents no problem for overlapping droplets or those with ovoid and elliptical shapes.

Pollen fertility

The strong positive correlation \((r^2=0.72)\) between diameter and fertility indicates that this parameter can be a useful one to categorise male varieties into fertility classes. In Cuba, Guerra et al. (1989) noted that highest fertility was observed in commercial varieties with pollen diameters in the range of 30-40 µm. Although a negative correlation was noted between Aspect Ratio and pollen fertility, it was too low \((r^2=0.12)\) to be significant. A larger number of varieties with a wider range of Aspect Ratios would have to be analysed in the future to confirm/infirm the hypothesis that pollen fertility is related...
to aspect ratio. It would also be desirable to test whether the percentage of each pollen stained has an effect on viability and hence on fertility. This could be adequately tackled by VIA.

**Measurement of sugar crystals**

The areas of the crystals correlated well with the calculated areas from one-dimensional measurements. When the VIA was used, the EQ was derived directly from the area of the crystal measured as compared to a derived area (length x breadth) which is approximate when crystals are measured with a scaled eyepiece. The VIA is thus better suited to analyse crystals which deviate from the standard square shape (Ness 1984). Moreover, the analyser allowed faster manipulation per unit time without compromising accuracy and the work was less tiring and more objective.

**CONCLUSION**

The VIA is a very versatile equipment which can perform quickly an array of tasks. The program included with such systems has many sub-routines. These include many mathematical transformations which enhance the raw image to facilitate processing. However, these transformations should be used only if necessary as they can sometimes affect results in a negative way. It is of utmost importance to stress that the performance of the system relies a lot on the ability of the user to prepare very good images especially as regards to uniform illumination. The applications developed at the MSIRI are only a small fraction of what the system can do. From the results obtained, it is evident that the use of VIA improved considerably on accuracy and rapidity in all the fields tested. The VIA could also be used in the future for the assessment of other foliar sugar cane diseases as well as in the preparation of field assessment keys in cases where they are not available such as for brown spot (*Cercospora longipes*) and yellow spot (*Mycovellosiella koepkei*). Other future applications include preparing karyotypes, scanning gels, automatic selection of interesting cell cultures in monoclonal antibody production and root surface area analysis.

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A CASE STUDY OF FARMER PARTICIPATORY RESEARCH:
THE OPTIMUM DENSITY OF TOMATO

N Govinden¹, R Rajcumar², B Gowrea¹ and K Rummun¹

1 Mauritius Sugar Industry Research Institute
2 Agricultural Research and Extension Unit

ABSTRACT

For the first time in Mauritius, the feasibility and effectiveness of the farmer participatory research method were assessed in a case study undertaken by MSIRI and AREU in 1998 and 1999. The optimum density of tomato was chosen for this study because, at present, few growers follow recommendations. Replicated trials were laid out on farmers’ fields in the main tomato production zones. The treatments - limited to six at each site – consisted of combinations of inter-and intra-row spacing, with one to three plants per hill, giving plant densities of 14,800 to 55,500 plants per hectare. Results of eight successful trials showed that standardized yield (i.e. yield % control) was a close quadratic function of the number of hills per hectare with an optimum at about 18,000 hills per hectare. This means that for optimum yields, various combinations of intra- and inter-row spacing and number of plants per hill can be adopted by growers, depending on their specific circumstances and site conditions. Essentially for lack of training and experience on the part of researchers, extension officers and growers alike, the participation of growers and the success rate of the project were low. So too, was the quality of the feedback received from participating growers and visitors to the trials. With appropriate improvements in methodology and communications, the FPR approach can be a useful, if not indispensable, adjunct to conventional research.

Key words: FPR, On-farm trials, Extension, Planting pattern.

INTRODUCTION

The recommended plant density for tomato in Mauritius is 25 000 plants per hectare which can be obtained by planting at spacing of 1 m between rows and 0.4 m between hills and by keeping one plant per hill (MSIRI, 1995). Planters rarely use the recommended spacing or keep one plant per hill. A recent survey showed that planters keep at least two plants per hill and use densities ranging from 30 000 to 55 000 plants per hectare (Govinden et al. 1997a). The recommended density optimises yield whereas farmers’ choice of densities and planting patterns is determined as much by socio-economic factors as by yield. The most important factor is profitability, but the cost, especially that of labour, is equally important.

The main objective of this project was to determine the density and planting pattern, which optimises profitability and, at the same time, is acceptable to farmers. A second objective was to use the project as a case study of farmer participatory research (FPR) method, and more specifically, to evaluate the feasibility and effectiveness of the method and to assess planters’ response. FPR involves the active participation of farmers from the conception to the end of the project. Farmers choose the treatments to be evaluated and conduct and manage the trials with the collaboration of extension workers and researchers. They participate in discussions on the results and assist in formulating the technology package for dissemination. The advantage of this approach is that a larger number of on-farm trials can be implemented in a given period, hence decreasing the time taken to generate and disseminate new technology. Socio-economic conditions of farmers are also taken into account, thus ensuring a higher level of adoption. The presence of extension officers in the research team, and the organization of visits to the trials for other farmers also lead to faster adoption.

This project was undertaken at the request and with the collaboration of the Agricultural Research and Extension Unit (AREU) following a workshop on the research and development needs of tomato during which the FPR approach had been recommended. (Govinden et al. 1997b).
MATERIALS AND METHODS

Choice of growers and sites

AREU officers contacted tomato growers in the main tomato production zones. These are located at the lower altitudes where temperature is higher and more conducive to tomato production. The trial sites (Figure 1) were chosen almost at random because very few farmers volunteered to participate in the project although many accepted seeds to plant in their fields. Nevertheless, the sites were sufficiently representative of the main tomato production zones of Mauritius.

Figure 1 Location of trials

About thirty farmers were contacted each year in 1998 and 1999. Initially many of them accepted to collaborate, but for one reason or another, they abandoned after sowing the seeds. Five trials were planted in 1998 and eight in 1999. Of these, only three were harvested in 1998 and five in 1999 for various reasons, especially drought which led to several trials being abandoned.

Treatments and cultural practices

The objectives of the trials, the methodology and the role of participating farmers and other team members were explained to the farmers, first at a group meeting and then individually. Each farmer chose from a range of inter-row and intra-row spacing those which he wanted to compare with his own. For practical reasons, the number of treatments was limited to six at each site (Table 1).

Similarly, plot size and numbers of replicates were constrained by field size, and compromises had sometimes to be made. Plot size varied from 43 m² for some treatments at some sites to 72 m² for others. Plots consisted of four rows. There were three or four replicates. Seeds were sown on beds or in plastic pots, and when the seedlings reached 0.1 m after about 3 weeks, they were transplanted to planting holes or furrows. Planters do not normally transplant; they prefer to sow 10 - 15 seeds per hole directly in the field and to thin the seedlings to the desired stand. Most cultural practices were left to the discretion of growers. Fertilization was not standard; some planters used only farmyard manure; others applied only chemical fertilizers, and others yet, applied a combination of both. Some trials
were weeded manually, once or twice, while others were treated with herbicides. Growers were advised on appropriate pest and disease control methods. The trials were harvested at the convenience of the farmers, usually every week. AREU Officers recorded the plots weights.

Variety Sirius was used in all the trials. This newly released variety has a determinate growth habit unlike variety MST 32/1 which is semi-determinate. It has a smaller canopy and, consequently, it should be planted closer than MST 32/1, but at the initiation of the project, few growers were familiar with the variety.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>No of sites</th>
<th>No of plants</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Inter-row</td>
<td>Intra-row</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ha⁻¹</td>
<td>hill⁻¹</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>14 815</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>18 519</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>22 222</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>24 691</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>24 691</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>27 778</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>27 778</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>29 630</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>33 333</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>33 333</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>37 037</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>37 037</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>41 667</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>44 444</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>49 383</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>55 556</td>
<td>3</td>
</tr>
</tbody>
</table>

Meetings, visits and feedback

In 1999, farmers were interviewed during the trials to record their views of the treatments and of the FPR approach, and to identify the problems encountered in implementing the trials. Visits were organized during which other planters from the area had the opportunity to evaluate the treatments and to discuss with collaborating planters, extension officers and the researcher. Results were later presented to planters at a meeting during which the extension package was discussed.

RESULTS AND DISCUSSION

Yield

Average yield varied from 9.4 t ha⁻¹ to 42.5 t ha⁻¹. Since all the trials did not carry the same treatments, the average yield across sites could not be analyzed statistically. However, the general trend is clear. As shown in Figure 2, up to a density of about 25 000 plants per hectare, yield increased with increasing plant density irrespective of planting pattern, the peak indicating the optimum plant density for maximizing yield. Thereafter, as plant density increased, yield decreased. This is due to the effect of competition between plants with increasing density. Normally, beyond this peak, the yield should fall off rapidly.
Figure 2 Average yield t ha⁻¹ of tomato variety Sirius as a function of plant density

However, in this series of trials, yield only decreased up to density of about 33,000 plants, and thereafter, it increased again. Thus, the response of yield to density was quite abnormal and is explained by the fact that density is a composite of three factors: the spacing between rows, the spacing between planting hills within the rows, and the number of plants per hill.

Each of these three factors affects yield. In order to compare yields across sites, they have first to be standardized, and this was done by expressing them as percentages of the control at each site (Table 2).

On average, yield increased with the number of hills per hectare and reached a maximum at about 18,500 (Figure 3). Also on average, three plants per hill yielded more than two plants per hill; this was the case even at 18,500 hills per hectare, indicating that there was more than enough space for three plants per hill, and that, therefore, the plants were not under competitive stress. At 24,692 hills per hectare, however, yield was higher with one plant per hill than with two, indicating that at this density the plants competed with one another.

The years 1998 and 1999 when the trials were conducted were exceptionally dry. Had the years been wet, perhaps the plants would have been more developed and the optimum yield would have been obtained with fewer plants. Generally, the more uniform is the spatial distribution of individual plants in a crop stand, the lower is the competition between plants. This is because upright plants tend to cover a circular surface around their base.

This is true of tomato which lies on the soil in a semi-prostrate position. Consequently, both the spacing between rows and the spacing between hills are important. A spacing of 0.5 x 0.5 m could have given the highest yield, but such a pattern is impractical. Indeed, inter-row spacings of 0.9 to 1.2 m are chosen for practical reasons, that is, to permit movement within the crop for weeding, spraying and harvesting.

Table 2 Yield (% control) of tomato variety Sirius as a function of planting pattern

<table>
<thead>
<tr>
<th>No of hills</th>
<th>Spacing between</th>
<th>Yield % control</th>
<th>Weighted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rows</td>
<td>Hills</td>
<td>No of plants per hill</td>
</tr>
<tr>
<td>ha⁻¹</td>
<td>m</td>
<td>m</td>
<td>1</td>
</tr>
<tr>
<td>7 408</td>
<td>1.5</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>9 260</td>
<td>1.2</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>12 346</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>13 889</td>
<td>1.2</td>
<td>0.6</td>
<td>-</td>
</tr>
<tr>
<td>14 815</td>
<td>0.9</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>18 519</td>
<td>0.9</td>
<td>0.6</td>
<td>-</td>
</tr>
<tr>
<td>Weighted mean</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>24 692 Control</td>
<td>0.9</td>
<td>0.45</td>
<td>100</td>
</tr>
</tbody>
</table>
Figure 3  Yield % control of tomato variety Sirius as a function of number of planting holes per hectare

![Yield % control of tomato variety Sirius as a function of number of planting holes per hectare](image)

Therefore, the inter-row spacing may not be reduced below a limit, whereas the intra-row spacing may be reduced and the number of plants per hill may be increased. The results show that the intra-row spacing should not be reduced below 0.45 m because competition between plants becomes effective and yield is significantly reduced. At this intra-row spacing, the number of plants should be limited to one per hill. Consequently, the highest number of plants with this pattern is about 25 000 plants per hectare. This corresponds to the recommendation and is applicable to tomato grown under good conditions. But the number of plants per hectare may be increased using a different pattern, as in some treatments in the trials. Up to 55 000 plants per hectare can be obtained with three plants per hill at an intra-row spacing of 0.6 m. This corresponds to most planters’ preference. It requires fewer planting holes and hence, reduces the labour required for digging holes and for watering. It also safeguards against poor development due to drought. Alternatively, planters who have access to equipment can also save on labour by planting in furrows.

**Lessons learnt about FPR, and proposals for improvement**

**Participation**

It was difficult to canvass planters to participate in the project although they readily accepted seeds of the new variety. Three reasons can be put forward for this poor response:

- Firstly, the concept was new to the growers since this was the very first time that they had been approached to participate in a FPR project. Although the responsibilities of the different partners were explained at length, many growers were reticent to participate.
- Secondly, most tomato growers in Mauritius have not had any training in tomato production. In future, such projects should only be proposed to those growers who have been trained in trial management which entails the commitment of time and resources on the part of growers.
- Thirdly, and as the growers indicated clearly in the interviews, a specific crop – tomato – and a specific project – optimum density – has been selected for the case study. Many growers were not interested in the crop or in the project.

In future it would be desirable to propose a few crops and a few projects from which individual growers can select their preferred ones. This entails establishing a programme at the beginning of the season with the participation of growers and implementing several projects simultaneously.

**Success rate**

Only eight trials were completed successfully over a period of two years. This low success rate was due to several causes.

- Firstly, many trials were abandoned before harvest because of drought; all three successful trials in 1998 were watered. Nevertheless, in future, trials cannot be restricted to irrigated sites because they would not be representative of the tomato production zone.
- Secondly, several trials were lost when seedlings were not transplanted in time. This occurred because of insufficient communication between the researcher, the extension officers and the
growers. The single researcher could not arrange to be present at planting at some sites, and the growers lost patience. In future, the extension officers may have to plant the trials whenever the researchers cannot be present when the growers are ready. Cellular phones may be needed to improve communications.

Feedback

The interviews of growers three times during the crop cycle – after transplanting, at first fruit formation and after final harvest – were found to be boring. Their usefulness was debatable since there were wide differences in the appreciation of individual treatments by different growers.

Thus, while the consensus was that wide interrow spacings (> 1.2 m) leave too much open space and favour weed infestation, there were diverging views on the merits of close interrow spacing (< 1 m). There was also consensus in favour of wide intra-row spacing (> 0.6 m) to minimize the digging of planting holes. Although the results showed clearly that one plant per hill was adequate, in the end, most growers remained sceptical. Most of them preferred at least two plants per hill, perhaps to safeguard against the risk of losing seedlings in case of drought, bacterial wilt, or other problems.

In general, collaborating growers as well as other growers who visited the trials were biased in favour of large plant development. In tomato, excessive vegetative growth may be at the expense of fruit production. This bias also explains the propensity to use excessive amounts of nitrogenous fertilizers and to apply foliar fertilizers as was found previously in surveys (Govinden et al. 1997a). In future, visits should preferably be organized late in the crop cycle when yield trends would have become noticeable. Moreover, yield data should be communicated to the visitors, perhaps in the form of figures written on plaques in front of each treatment.

CONCLUSION

In determinate tomato, a minimum inter-row spacing of 0.9 m is required to permit movement in the field for weeding, spraying and harvesting. At this inter-row spacing, an intra-row spacing of 0.5 m with one plant per hill gives the highest yield under optimum conditions. However, in order to minimize labour, it is advisable to either plant in furrows or to widen the intra-row spacing and to plant two or three seedlings per hill, giving plant population densities of 37 000 to 55 500 plants per hectare. These can be proposed when seeds are saved for planting and when plant development is limited, such as for instance, under rain fed conditions.

Because of lack of experience and training on the part of researchers, extension officers and growers alike, several problems were encountered in the implementation of this first case study of farmer participatory research, and the results were not up to expectations. Nevertheless, and after improvement in methodology and communications, the approach can become a useful adjunct to conventional research. Its greatest merit is that it promotes the participation of non-researchers in the research and development process.

ACKNOWLEDGEMENTS

Thanks are presented to the Deputy Director (Biology), MSIRI and to the Assistant Director (Extension and Training), AREU for coordinating the project; to the Senior Extension Officers, Extension Officers and Extension Assistants, (AREU) for implementing the trials and collecting data; and to collaborating growers for managing the trials and providing inputs and feedback.
REFERENCES


A THREE-PHASE APPROACH (OPI) AS A RESEARCH METHODOLOGY TO CONDUCT IN-DEPTH INVESTIGATION ON THE AGRICULTURAL ACTIVITIES OF SMALL-SCALE FARMERS

G Naidoo

Faculty of Agriculture, University of Mauritius

ABSTRACT

This paper describes a field approach (OPI) to conduct research with small-scale farmers. The advantages and disadvantages of this approach are compared and contrasted. The OPI approach deals with a preliminary circumspective phase, followed by increasing involvement with respondents and a further testing of preliminary conclusions with respondents for their confirmation of findings. The approach is discrete and in-depth so as to obtain as much reliable information from the group being studied whose entities are not considered merely as respondents but also as active participants. This approach is specially relevant where the researcher has more time for field work such as in longitudinal studies.

Keywords: OPI approach, small farmers, cattle keepers, grounded theory, triangulation, interview, ethnography.

INTRODUCTION

Studies have commonly used a RRA (rapid rural appraisal), PRA (participatory rural appraisal) or survey method to obtain information on agricultural activities in an area. This study focuses on a new approach which is called the OPI method. This method may be used when the researcher has several months to conduct an investigation, which is therefore suitable for research projects conducted by universities or agricultural institutions. The method is holistic and involves ethnography so as to obtain maximum information on the group or area under study to form more reliable conclusions. The approach depends mainly on a qualitative analysis and would not be suitable for quantitative agronomic or animal husbandry techniques. It leads to grounded theory in a previously unfamiliar area, from which theoretical propositions can be formulated at the end of the study instead of the research being guided by a set theory at the beginning. It is suitable to be used in a region where the researcher has had no previous contact with the farmers and the farming environment being studied.

RESEARCH METHODS

The site selected was the Canot / G.Cailloux area on the western coast of Mauritius island where an intensive local study was conducted. This was preferred to a broader survey approach. It was desirable to have more qualitative than quantitative data to enable the social reality to be constructed from the perspectives of the local people themselves. The aim of the ethnographic approach was to be ‘inside’ the system studied in order to understand better the people involved. This access to the ‘inside’ of the farming system was then compared and contrasted with an ‘outside’ and a border or ‘periphery’ view. The approach followed was thus conceptualised as one of progressing through an ‘outside’ (O) to a ‘periphery’ (P) and finally an ‘inside’ view (I). This was termed the ‘OPI approach’ in the study. It was intended to be discrete and a succession of increasing interactions with the people studied.

The OPI methodology used direct and participant observation, that is observation without or with interaction with respondents (Cohen and Manion, 1989). In the ‘O’ approach or outside approach, there was an initial period of direct observation of the cattle keepers going about their daily activities by walking around or travelling on public transport through the village, observing how people
A three-phase approach (opi) as a research methodology to conduct in-depth investigation on the agricultural activities of small-scale farmers. G.Naidoo

interacted with each other through their conversations or otherwise but not attracting attention on oneself (e.g. through visible use of the camera). They were observed from a distance with no direct contact made with them. Some cattle keepers were identified through direct observation during this phase. This ‘O’ approach continued throughout the field study period of twenty one months, to observe the cattle keepers in relation to their management of information in order to continually check the issues which arose. The field work was done on foot to reduce the status difference between the researcher and the studied population. No village leader was asked to accompany the researcher to the cattle keepers because of possible bias of the former in influencing responses.

The next stage (the ‘P’ approach) was to move closer to the respondents by establishing ‘rapport’ and through the use of semi-structured individual interviews to get insights into the way information was being managed from the cattle keepers’ own perspectives. The conversation was in Creole and Calcuttea languages with which respondents were more familiar. Only one or two interviews could be conducted per day as it took several hours to recall and record them afterwards. The interview questions were semi-structured and open-ended to collect qualitative and quantitative data. The researcher introduced himself briefly mentioning the institution where he was employed and that his study was about knowing more how the cattle keepers performed their activities. In this ‘P’ or periphery approach, there was participant observation, i.e. a preliminary contact with respondents and interviewing coupled with observation of the issues raised. After each interview, names and addresses of more cattle keepers in the area were obtained from those interviewed. Thus it was a ‘snow ball’ or ‘cluster’ approach although eventually all the cattle keeper population in the study area were interviewed.

Questions were noted on paper just to glance at whenever necessary. No distractive methods were used, such as taking notes during the interview with pen and paper. Instead notes of the interviews were recalled and recorded each time immediately after the researcher left the study area. This was assisted by mental pictures associated with the interviews, and also by looking at the prepared questionnaire (not shown to the interviewee) as a check list. The account of each interview was written as if the respondent was speaking (i.e in the first person). In order that the respondents did not feel they were only giving information and not receiving anything in return, some technical advice was given to them where relevant as part of the participant observation process. Empathy is preferable than equating scientific rigour with aloofness.

The first interviews helped to penetrate the information system. They gave rise to leads which were probed in the second, more focussed and semi-structured one to one interviews (the ‘I’ or inside approach). In this third approach, there was further participant observation to collect qualitative and quantitative data to cross check the answers through probing questions to establish commonality of responses so as to confirm patterns of responses from the first interviews. A further stage in the ‘I’ approach was to take the preliminary conclusions about the management of information which emerged from analysis of data back to the farmers for their assessment and if necessary modifications. Further insights were obtained as they ranked issues which confronted them in their daily activities. The emerging theoretical propositions or hypotheses were then listed at the end of the study as a guide for future research. Triangulation of the methods used was done in the course of collection and interpretation of data, to strengthen its reliability through comparison. This was done by checking the second interview responses (‘I’) with the first responses (‘P’) and also with observations from the ‘O’ approach.

RESULTS AND DISCUSSION

It was found that a pattern of behaviour existed when at least 5 respondents in the ‘P’ approach spoke specifically about an issue, without being prompted by the researcher from a total of 59 respondents. Similar conclusions about emerging patterns of responses from among only few respondents in samples studied as being indicative of the general responses were put forward in other studies (Ajzen and Fishbein, 1980; Valdiviezo, 1988; McKemey, 1996; Oblitas, 1997). When at least 10 respondents made closely resembling statements during the first interviews (‘P’), the pattern was assumed to be strong. In the second probing interviews, frequencies of responses were obtained and could be compared with patterns to triangulate issues, and placed in triangulation tables e.g. (Table 1).
A three-phase approach (opi) as a research methodology to conduct in-depth investigation on the agricultural activities of small-scale farmers. G. Naidoo

**Table 1** Triangulation table for information on nutrition in cattle keeping

<table>
<thead>
<tr>
<th>'P' approach producing patterns</th>
<th>n1</th>
<th>'I' approach producing frequencies</th>
<th>n2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy cow feed not cotton seed cake</td>
<td>5</td>
<td>Buy Cow feed containing molasses</td>
<td>51</td>
</tr>
<tr>
<td>Give 'poonac' (cowfeed) in water</td>
<td>12</td>
<td>Give 'poonac' in water</td>
<td>51</td>
</tr>
<tr>
<td>With more concentrates, there is no extra returns and animal pants</td>
<td>5</td>
<td>Feed less concentrates, no extra returns on feeding more</td>
<td>34</td>
</tr>
<tr>
<td>There is a lack of feeds at sale centre</td>
<td>5</td>
<td>There is a lack of feeds at sale centre</td>
<td>30</td>
</tr>
<tr>
<td>Fencing by sugar estate causes difficult access to fodder</td>
<td>15</td>
<td>Fencing by sugar estate causes difficult access to fodder</td>
<td>34</td>
</tr>
<tr>
<td>Collect fodder through fencing of sugar estates</td>
<td>23</td>
<td>Collect fodder through fencing of sugar estates</td>
<td>38</td>
</tr>
<tr>
<td>Have transported fodder via irrigation canals</td>
<td>5</td>
<td>Have transported fodder via irrigation canals</td>
<td>21</td>
</tr>
<tr>
<td>Aware of poultry litter feeding on sugar estate</td>
<td>6</td>
<td>Aware of poultry litter feeding on sugar estate</td>
<td>35</td>
</tr>
<tr>
<td>Give rice water to cattle</td>
<td>6</td>
<td>Give rice water to cattle</td>
<td>55</td>
</tr>
<tr>
<td>Give common salt in water</td>
<td>5</td>
<td>Give common salt in water</td>
<td>52</td>
</tr>
</tbody>
</table>

*n1* = number of observations or responses in ‘P’ approach  
*n2* = number of responses in ‘I’ approach

Another outcome of the OPI approach was the structuring and ranking of nine issues of importance to the cattle keepers in conducting their cattle keeping activities in the following order of importance:

- Nutrition
- Sale
- Land
- Veterinary
- Peer relationship
- Finance
- Housing
- Stock renewal
- Storage and retrieval of information

The theoretical propositions that emerged from the study and which could be used for future studies were:

- Elders in the family are an important source of information whilst printed information is less used
- Cattle keepers are more interested to have information on how their produce will be sold than on how to produce more, and they are not interested to market their produce themselves
- Cattle keepers are more concerned about buying prices of inputs than about sale prices of produce from their houses
- Cattle keepers use more veterinary information than information from extension services
- There are covert processes of information diffusion among cattle keepers which equalise their knowledge level about cattle keeping
- Small-scale cattle keeping is conducted by agricultural employees with a low level of schooling to improve their housing conditions
- Cattle keepers maximise the use of natural resources in their environment to keep down costs
- Cattle keepers display the group spirit only when there are common problems to be addressed
- Children of cattle keepers are not interested to continue cattle keeping

The overlying theory emanating from the results is that there is an interaction between the sources of information and the working knowledge of the cattle keepers, influenced by their personal characteristics, to give rise to a series of information management processes which eventually lead to acquiring new knowledge.
A three-phase approach (OPI) as a research methodology to conduct in-depth investigation on the agricultural activities of small-scale farmers. G. Naidoo

CONCLUSIONS ON THE METHOD USED AND IMPLICATIONS FOR OTHER STUDIES

The ‘OPI’ approach helps the researcher to approach farmers with sensitivity, to observe variations in behaviour and after a preliminary analysis of data, to revisit the farmers to confirm the conclusions about their management of information drawn from their responses. It allows the results to be re-interpreted by testing the researcher’s findings and their reliability.

The value of the OPI approach lies in the fact that it is a slow, careful and discrete interaction strategy where the researcher does not know the group being studied well, and cannot predict what the reaction of respondents will be to the presence of an outside researcher in their midst. The researcher comes as an equal to the respondents so as not to be looked upon as a stranger depicting an attitude to learn from their perspective rather than as a provider of ready-made solutions. One can sense the friendliness or hostility of respondents and re-adjust before going deeper. It is a suitable method when the researcher does not come as a representative of a donor organisation and cannot offer much material support in return for respondents’ cooperation. The researcher observes them well before establishing contact so as to be able to prepare questions to ask. It takes time to build up the relationship. There is empathy and respect of the local language and culture to gain the confidence of the respondents. The researcher collects data over a period of time through continuous rather than through quick interaction. The method of recording information after the interview can be beneficial as a training to help interviewers obtain maximum interaction with their respondents. Although some information may be lost before recording, this method appears to allow information to be readily provided by the interviewees as there is less threat and inhibition than in simultaneous recording. Approaching the village on foot helps the research process by not projecting an image of higher status, instead of one of equity. The leads obtained in the first interviews from at least 5 out of 59 respondents are judged to make it likely that this is the way the majority feels over the same issues. Thus the initial responses serve as indicators. This can be shown in triangulation tables where the statements from leads and probes are given. Predictions are therefore possible although the data are mainly retrospective and current. Where lower figures appear during probes, these need to be investigated further to throw light on the apparent discrepancies as there may be more than simply numerical explanations for this.

Key lessons learned about the practical logistics of such an approach are that there is increasing exposure to the researcher and the respondents progressively. It allows multiple sources of evidence like participant observation, interviews, study of documents and case study, which improve the standard of the research as compared to a single source of evidence. It explains causal links in a real life phenomenon which is too complex for a survey to investigate. It increases trust to give true answers and the researcher can get an understanding of the working knowledge of respondents. What respondents say can be observed and tested, so respondents cannot lead the interviewer astray. The patterns and frequencies help to triangulate responses. Time is needed for such a study, which is suitable for a longitudinal study with a relatively small sample.

The OPI approach enables a grounded theory to emerge out of the data instead of a theory being imposed on it as hypothetical propositions at the beginning. The implications for grounded theory is that it essentially replaces a preliminary awareness study. It is a productive and structured way to develop a theory as an iterative process rather than the more rigid hypothesis testing approach of traditional research.

This methodology allows more information to be obtained because there is more observation and people speak in breadth and depth also. The enumeration of hypotheses which emerge may enable future researchers to start their research with these as basis. The approach throws light on a little known phenomenon in its real life context from different angles and from the perspectives of the population studied. It is a suitable method when there are ‘how’ and ‘why’ questions to be investigated. Some isolated remarks can lead to interesting probes, which increase insights and penetration of covert issues such as ‘evil eye’ and ‘indigenous’ treatment of cattle. One does not impose a set of questions on the respondents early. The researcher may have to learn the questions and develop them and probe the answers during interaction. There is more cooperation from respondents by being continuously present in their midst.

‘OPI’ is a useful method as there is more time to concentrate on all respondents and avoid depending on a few key informants who may be biased. However the researcher has to provide some inputs in return to get more cooperation from the respondents, and make them more willing to answer the
A three-phase approach (opi) as a research methodology to conduct in-depth investigation on the agricultural activities of small-scale farmers. G.Naidoo

questions. OPI is not suitable for survey interviews where a quicker interaction is required by the researcher.

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PRODUCTION OF MAJOR COLOCASIA SPP. IN MAURITIUS: CURRENT STATUS, CONSTRAINTS AND OPPORTUNITIES

S Jugurnauth, S Soomary and P Hanoomanjee

Agricultural Research and Extension Unit

ABSTRACTS

Colocasia leaf blight Phythophthora colocasiae, which was recorded in Mauritius in 1995, drastically reduced the taro Colocasia esculenta (L.) Schott production from 480 tonnes (1993) to 45 tonnes (1997). A strategy was developed to boost up production. In this connection, a survey was carried out to have a better understanding of the constraints and current practices involved in the production of colocasia, and to study the incidence of leaf blight over time in selected regions island-wide. Concurrently, some research experiments were performed in order to identify new opportunities and test new cultural practices liable to improve the production of this crop.

The study shows that the sub-humid regions may be considered as low risk areas with respect to leaf blight incidence and taro production can be effected throughout the year, provided an irrigation facility is used. On the other hand the humid and super-humid regions are considered as high risk areas where it is advisable to grow only one crop during the year, starting preferably in June. Results from the field trials on taro show that the highest crop yield was obtained in the sub-humid regions (30.1 t / ha) compared to humid and super-humid regions where the yields of 16 t / ha and 21 t / ha were recorded respectively. During the survey many malpractices in crop management with respect to fertilisation, weeding, irrigation, sanitation etc were also noticed.

As regards the trial set up to identify the fungicide which were most effective in the control of colocasia blight, the best result was obtained with Ridomil Gold MZ 68 (Metalaxyl + Pencozeb) at 2 g / l using Bacoil (adjuvant) at 35 ml / l.

Keywords: colocasia, colocasia blight, taro, low and high risk.

INTRODUCTION

Taro (Colocasia esculenta (L.) Schott) is a herbaceous perennial plant belonging to the family Araceae. Its shoot consists mainly of leaves with long petioles, formed in a whorl at the apex of the underground corm which is also the main storage organ. The lower part of the corm produces numerous roots and several cornels which arise from its axillary buds.

Taro originated in the Indo-Malayan region of South East Asia (Chang, 1958), from where it spread to the Pacific and Mediterranean regions and later to Africa. Taro is a commercial crop in many countries like, Egypt, Hawaii, Pacific and Caribbean Islands and the Philippines.

The cultivated species of taro may be distinguished into two main groups - the eddoes types and the dasheen types. One example of the eddoes types is the Colocasia esculenta var antiquorum which is locally known as “Arouille cari.” The side tubers or cornels may become as big as the mother corm and can occur from 5 to 20 in number. In the dasheen types which are locally represented by the Colocasia esculenta var esculenta (comprise “Arouille violette” and “Songe”.) the side tubers or cornels are usually absent and the mother tuber or corm is the main storage organ. Both the corms and cornels of taro are edible. They contain about 20 - 22 % of starch and significant amounts of calcium, phosphorous and vitamin C (Kay 1973). They can be consumed boiled, baked or roasted or fried. The leaves of taro (Songe) are also eaten as they contain about 23% of protein on a dry weight basis. It should be noted that unless properly cooked, the corm, cornels and leaves of taro can have an irritating effect on the skin, tongue and throat. This is normally referred to as acridity and
occurs due to the presence of purple needle like raphides which are minute bunches of calcium oxalate crystals.

In Mauritius taro is grown extensively in the north particularly in the humid regions of Crève Coeur, Montagne Longue, Les Marianes, Congomah. It is also found in marshy regions: Bambous, Clementia, Schoenfeld, Careau Acacia. The production of taro has fallen drastically from 480 t in 1993 to 45 t in 1997 with a subsequent increase in its retail price on the local market.

The drop in production is due to the epidemic outbreak of colocasia leaf blight (*Phytophthora colocasiae*) which was first recorded in Mauritius in 1995. The disease is expressed on leaf lamina by small dark and round lesions, rapidly enlarged to 2.5 - 5.0 cm in diameter when conditions are favourable. Drops of clear liquids exude from the necrotic spots and turn pale yellow when dry. As the disease progresses, the spots coalesce and have characteristic rings of brown colour. The disease may kill entire leaves and may infect petioles as well causing severe damage to the plant, leading to a drastic reduction in yield. Given the lack of effective control measures against this disease, the production of taro could no longer be sustained in many parts of the island. It should be noted that similar situations have prevailed in India, Indonesia and some Pacific countries where crop losses up to 50% have been reported (UNDP / FAO, 1991)

Given the very limited level of local research performed on *Colocasia* spp., there was a need to revisit this crop with a view to boost up local production. In this connection, a survey was carried out to have a better understanding of the constraints and current practices involved in the production of colocasia, and to study the incidence of leaf blight over time in selected regions island-wide. Concurrently, some experiments were laid out in order to identify new opportunities and test new cultural practices liable to improve the production of this crop.

**MATERIALS AND METHODS**

The survey was conducted in the 4 regions of the island (North, South, East and Centre / West) in the main taro growing localities. A random sample of 16 growers was selected from a total of 83 having taro plantations during the period of the survey (April 99 – May 00).

The selected growers were interviewed using a questionnaire designed to tap information on the agronomic and cultural practices currently used by them on their plantations.

A plot measuring 100 m² was earmarked in a field of each of the 16 selected growers. Fifteen plants in each plot were selected at random and tagged for observations. The parameters observed were: total number of leaves and total number of infected leaves from which the percentage of infected leaves was calculated. Data were collected at monthly intervals.

Separate trials on stations were set up in April 99, using a Complete Randomised Block Design with plots measuring 121 m² having 360 plants, in three localities namely Wooton (Super-humid), Réduit (Humid) and Richelieu (sub-humid) with the objective to assess the growth and yield of taro in the three agro climatic regions. The crops were harvested six months after planting. The performance was assessed in terms of the number of cormels per plant, the average weight and yield of cormels and corms, the level of leaf blight infection and the growth rate.

Trials in planters fields at Bramstan, were conducted to evaluate the efficacy of 3 fungicides, Ridomil Gold MZ 68 (Metalaxyl + Pencozeb) at 2 g / l, Melody Duo (Iprovalicarb and Propineb) at 4 g / l, Melody Duo at 6 g / l and Copper-Oxychloride at 3 g / l) under field conditions, using two adjuvants (Complement at 5 ml / l and Bacoil at 35 ml / l) for control of Phytophthora leaf blight on *Colocasia esculenta* (Arouille violette).

In addition to the primary data, average monthly temperatures, relative humidity and rainfall prevailing at the observation sites were collected from the Meteorological services in order to assist in the interpretation of the experimental results.
RESULTS AND DISCUSSION

Survey Findings

Plantation

Based on the information gathered from the survey, it was found that eddoes crops are mostly grown in the North. Some 68% of the growers interviewed raise the taro crop on marshy land. In 87% of the cases the land was flat. It was observed that 56% of the colocasia crops were raised in the sub-humid zone under flooded conditions whereas 13% and 31% of the crops were found in the super-humid and humid zones respectively.

Land preparation and pre-planting practices

The survey indicated that land preparation for the production of Colocasia spp was performed manually. The crops are raised in holes at spacing which varied from 20 cm x 20 cm to 50 cm x 50 cm. However, many growers used a spacing of 30 cm x 30 cm. As regards the planting season, most of the growers started their crops at the beginning of summer namely during the month of September to October. Planters in the South, however, preferred to start their crops in the month of December and January with the coming of the rainy period. It was also observed that 44% of the colocasia growers used the mother corm and the same percentage used the sucker cormel whereas 12% of the growers used the stem top as planting material. No treatment of planting materials was done prior to planting.

Post-Planting cultural practices

The level of adoption of the main cultural practices used by farmers with respect to fertilizer application, weeding, earthing up, removal of infected leaves, pesticide use and irrigation were observed during the survey and are illustrated in Table 1. Regarding fertilisation practice, only 63% of the growers applied fertilisers to their crops. It was noted that the current rates of N, P2O5 and K2O used by the growers varied from 8.5 to 136 kg N / ha, 4 to 190 kg P2O5 / ha and 10 to 100 kg K2O / ha respectively with an average of 40 kg / ha for N, 53 kg / ha for P2O5 and 40 kg / ha for K2O. This can be compared with the recommended rates which are 110 kg of N / ha, 230 kg P2O5 / ha and 180 kg of K2O / ha. (Le guide de culture, 1998) This implies that all of the growers were applying fertilizers below the recommended rates. In cases where the crops are raised under flooded conditions practical difficulties were experienced by the growers to fertilize the crop.

Concerning irrigation practices, the survey indicated that 56% of the Colocasia crops were being grown under flooded conditions. This mostly applied to Colocasia esculenta (A. violette), found in the South and West in localities namely Careau Acacia, Albion and Bambous. As regards crops raised in dry lands only 6% of growers irrigate their crop using the overhead system. This occurs mainly in C. esculenta var. antiquorum (A.cari) grown in Crève Coeur and Riche Terre. However, 44% of the growers found in superhumid and humid zones raised Colocasia crops under rainfed conditions.

As regards to crop sanitation, it was observed that although 75% of the growers practiced a proper weeding only 31% of them maintain a good sanitation by removal of infected leaves. This was found to be very useful in reducing the inoculum pressure of the colocasia blight disease leading to a better plant growth and development.

As far as leaf blight disease control is concerned, it should be mentioned that traditionally growers did not use pesticides on Colocasia, however with the outbreak of Colocasia blight, the use of pesticide application has become very important. The survey, however indicates that only 20% of growers applied pesticides, mainly Ridomil (Metalaxyl) or Copper-Oxychloride or Dithane M45 at the rate of 2-5 g / l. The growers also pointed out that the control was not quite effective.
Table 1 The agronomic practices adopted by growers

<table>
<thead>
<tr>
<th>Agronomic practices</th>
<th>Adoption by growers %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthing up</td>
<td>31</td>
</tr>
<tr>
<td>- Weeding</td>
<td></td>
</tr>
<tr>
<td>- Manual</td>
<td>75</td>
</tr>
<tr>
<td>- Chemical</td>
<td>25</td>
</tr>
<tr>
<td>Removal of infected leaves</td>
<td>31</td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>- Overhead</td>
<td>6</td>
</tr>
<tr>
<td>- Flood</td>
<td>50</td>
</tr>
<tr>
<td>- Drip</td>
<td></td>
</tr>
<tr>
<td>- None</td>
<td>44</td>
</tr>
<tr>
<td>Fertiliser application (mostly 13:13:20:2)</td>
<td>63</td>
</tr>
<tr>
<td>Pesticides use</td>
<td>20</td>
</tr>
</tbody>
</table>

Disease development

The development of colocasia leaf blight was recorded monthly in selected plots belonging to planters in the three agro-climatic zones namely: the sub-humid, humid and super-humid in specific localities found in the North, South, East, West and Centre. The variation in infection level over time in the respective regions is illustrated in Figure 1.

It is observed that in general the level of infection decreases over time to reach a minimum in December and a peak in May. In the sub-humid regions namely North, South, West (in localities such as Richeterre, Poudre d’Or, Carreau acacia, Ferney and Flic en Flac) the level of infection was low (0 – 10 %) and taro cultivation can be effected throughout the year provided an irrigation facility is provided.

In humid regions especially in the East (in localities like Bramstan and Clemencia), the level of infection was in the range of 7 – 49 %. In super-humid regions such as Highlands the level of infection ranged from 20 to 47 %. Thus the level of infection is higher in the super-humid regions, with a low infection between July and December. This indicates that one crop of colocasia can potentially be produced in the humid and super-humid regions. This is feasible if the crop starts in June, given the risk of disease incidence is relatively lower compared to the period between January and May.

The trends in the level of disease infection at monthly intervals were also studied in relation to the relative humidity, rainfall and temperatures prevailing at the observation sites. Results for the south and centre are illustrated in Figures 2, 3, and 4.
It was observed that at low level of relative humidity (70 – 75 %) which prevailed from May to December a low level of infection (0 – 15 %) occurred. As the relative humidity increased from 75 to 82 % the level of infection also increased from 20 to 30 % Figure 2.

Figure 2: The level of leaf blight and relative humidity over time

Similarly trends were observed for the level of infection in relation to rainfall as illustrated in Figure 3. There was low infection 0 – 5 % between August and December when there was low monthly rainfall 0 - 50mm.

Figure 3: The level of leaf blight and rainfall over time

However, it was observed that the level of infection of colocasia blight was as high as 30 % when the temperature was low (15 °C) from May to September. The level of infection decreased from 30 to 15 % between September and April when the temperature increased from 15 to 20 °C (Figure 4).

Research findings

The research activities on taro were aimed at improving cultural practices with a view to identify new opportunities and better crop management practices for the production of colocasia spp. One set of trials was run in April 99 at the three research stations namely Wooton (Super-humid), Réduit (humid) and Richelieu (sub-humid) with the objective to assess the growth and yield of taro in the three agro-climatic regions. Another set of fungicides trial was also performed at Bramstan in Flacq with a view to assess the efficacy of three fungicides namely Ridomil Gold MZ 68, Melody Duo and Copper Oxychloride using two adjuvants (Complement and Bacoil) for the control of phytophthora leaf blight on Colocasia esculenta. The results of the agronomic trials are shown in Table 2.
Production of major colocasia spp. in mauritius: Current status, constraints and opportunities. S.Jugurnauth et al.


42

Figure 4 The level of leaf blight and temperature over time

Table 2 Crop performance of taro at Wooton, Réduit and Richelieu Crop Research Stations

<table>
<thead>
<tr>
<th>Site</th>
<th>Average cormels per plant</th>
<th>Average wt. of cormel</th>
<th>Average wt. of corn</th>
<th>Yield of corm</th>
<th>Yield of corn</th>
<th>Total yield</th>
<th>Average no. of leaves 5 months after planting</th>
<th>Average plant height 5 months after planting</th>
<th>Growth rate per month</th>
<th>Leaf Blight, infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wooton</td>
<td>3.7a</td>
<td>14.3a</td>
<td>137.5a</td>
<td>6.1a</td>
<td>15.0a</td>
<td>21.1a</td>
<td>3</td>
<td>34</td>
<td>5</td>
<td>severe</td>
</tr>
<tr>
<td>Réduit</td>
<td>5.7b</td>
<td>14.0a</td>
<td>99.5b</td>
<td>6.0b</td>
<td>10.6b</td>
<td>16.1b</td>
<td>5</td>
<td>44</td>
<td>10</td>
<td>Mild / High</td>
</tr>
<tr>
<td>Richelieu</td>
<td>5.6b</td>
<td>29.5c</td>
<td>154.5c</td>
<td>15.2b</td>
<td>14.9b</td>
<td>30.1c</td>
<td>5</td>
<td>86</td>
<td>22</td>
<td>very low</td>
</tr>
<tr>
<td>S.E ±.</td>
<td>0.3</td>
<td>1.7</td>
<td>8.2</td>
<td>0.9</td>
<td>0.9</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is observed that the highest total crop yield comprising both the corms and cormels was obtained at Richelieu (30.1 t / ha) followed by Wooton (21.1 t / ha) and Reduit (16.1 t / ha) respectively. In fact the plant growth and development rate as reflected by the average number of leaves and plant height attained at 5 months after planting were also highest at Richelieu (4.9 and 86 cm) compared to Réduit (4.6 and 43.9 cm) and Wooton(2.9 and 34.3 cm). Also the level of leaf blight incidence was very low at Richelieu compared to Réduit and Wooton where the incidence was mild and severe respectively. This indicates that the potential to grow Colocasia crops in the sub-humid regions especially in localities like Richelieu cannot be ignored.

Results of on-farm trials at Bramstan indicated that all fungicides evaluated gave positive fungicidal action compared to the non -sprayed control. Best control was obtained with Ridomil Gold MZ 68 at 2 gm / l plus Bacoil (adjuvant) at 35 ml / l.

CONCLUSION

Based on the observations made during the survey regarding the level of infection of colocasia blight on taro over time in the different localities in the main agro-climatic zones (Sub-humid, humid and super-humid) and supported by the crop performance trials carried out in the three zones, it is concluded that production of taro can be effected with a very low risk of colocasia blight in the sub-humid regions throughout the year. However, this production is not possible unless adequate irrigation facilities especially drip irrigation systems are provided as shown from results of trials conducted at Richelieu CRS.
In the super-humid and humid regions the level of infection is high except from June to December when the infection is relatively low. So it is advisable to grow only one crop of colocasia, starting from the month of June with a reasonably low risk of disease incidence.

In periods of heavy rainfall (December to April) the relative humidity is too high leading to high levels of infection. Hence the disease control measures should be reinforced. Crop sanitation should be strictly observed by regular removal of infested leaves. Regular fungicidal sprays at 10 day intervals using Ridomil Gold MZ 68 (Metalaxyl + Pencozeb) at 2 g / l plus Bacoil as adjuvant at 35 ml / l should be maintained.

Based on the survey findings, many shortcomings were identified in the crop management practices, such as lack of fertiliser use, utilisation of untreated planting material, inadequate crop sanitation, and lack of pesticide use. It is believed that these could be eliminated to a great extent through a more aggressive advisory programme that would lead to a general improvement in the crop management practices for taro production.

REFERENCES


ALTERNATE SUBSTRATES FOR ANTHURIUM PRODUCTION

Rita Nowbuth
Agricultural Research and Extension Unit

ABSTRACT

Anthurium andreanum var. Ozaki was used in a substrate evaluation study at Réduit and Wooton Crop Research Station. The substrates evaluated were of inert nature (Chipping 3/8, rocksand 2 mm and rocksand 4 mm) and of organic nature (bagasse, flyash, scum, sawdust and poultry litter). At Réduit Crop Research Station, the inert substrates were evaluated singly; the organic substrates like flyash, scum and poultry litter were mixed with soil in a ratio of (1:1) whereas bagasse and sawdust were mixed with manure and soil in a ratio of (1:1:1). At Wooton Crop Research Station, all substrates were used in combination with manure and soil in a ratio (1:1:1). Parameters measured were flower production, flower size, flower stalk length and spadix size. Data were collected for one year. The results obtained showed that at Wooton materials like chipping, rocksand 2 mm, rocksand 4 mm, bagasse, sawdust and poultry litter when used in combination with manure and soil gave larger flower sizes and higher flower production. As for Réduit CRS, bagasse, sawdust, scum and flyash used in combination with soil appear to be the more promising substrates.

Keywords: Anthurium, growing media, inert substrate, organic substrate, bagasse, scum, flyash, poultry litter, sawdust, rocksand 2mm, rocksand 4mm and chipping 3/8.

INTRODUCTION

Introduced from Hawaii in 1956 and from Brazil in 1965, anthurium has been commercially cultivated in Mauritius around 1967 (Anon, 1989). Since then growers have gained a lot of expertise in the cultivation and exportation of anthurium blooms. Thus Mauritius finds itself to be the fourth most important flower exporter among the ACP countries, the first most important anthurium exporter to European countries and the second most important anthurium exporter following Holland on the world market (Anon, 1996). The main step now is to keep up with the expanding anthurium industry worldwide. This can be achieved by the introduction of new varieties and amelioration of cultural practices.

One of the most important components of anthurium cultivation is the choice of growing substrate or medium. Anthurium is known to grow best in a well-aerated medium with good water retention capacity and good drainage. A good medium needs to be able to anchor the roots and stems so that the plant will not topple over as it grows larger, yet it should provide sufficient moisture, nutrient and aeration to the plant. As stated by Ing. Marco Van Hert et al. 1998, the growing media commonly used can be either inert (rockwool, polyphenol foam, rocksand, lava stone and other types of foam) or organic (coconut shell, peat, bagasse, sawdust, rice husks or tree bark). The inert medium offers the advantage of being stable for several years. The most important consideration with these media is the use of appropriate fertilizers. As for organic media, they decompose over time causing the rotting of the roots on the bottom of the beds due to compaction and water accumulation. Thus the addition of a new layer of medium to the bed is needed to stimulate rejuvenation of the plants (Ing. Marco Van Hert et al. 1998).

Studies on growing media for anthurium production have shown that anthurium can be cultivated on a number of media (Higaki et al. 1978, 1985(a) and 1985(b)). Earlier studies on substrates in Mauritius have shown that anthurium can be grown successfully in a mixture of soil: bagasse (2:1) (Anon 1982, 1983, 1984, 1985, 1986 and 1987). Our commercial growers however use various combinations of soil, farmyard manure, sugarcane bagasse and cane ash (Anon 1989). However bagasse is becoming scare since it is being used for the production of electricity by sugar estates (Anon 1998).
Justification

During a workshop among members of APEXHOM and research officers of AREU in 1997, the problem of availability of bagasse for the cultivation of anthurium was raised. The need for identifying an alternative substrate for the production of anthurium was evoked. This need was also expressed by Timothy K. Broschat 1997. The main objective of this study was to identify a locally available substrate that could be used for anthurium cultivation.

MATERIALS AND METHODS

The study was set up at Réduit Crop Research Station (RCRS) and Wooton Crop Research Station (WCRS) in shade houses with 80 % shade on top and 50 % shade on the sides. A completely randomised block design with three replicates was used. To ensure isolation of all substrates under study, the planting bed was constructed by laying concrete blocks on the soil surface to form a basin. The length of the planting bed was 13 m, the width 1 m and depth 41 cm. The bottom of the planting bed was lined with black plastic sheet to isolate the medium from the soil underneath. Each planting bed was partitioned to represent the three replicates for each treatment. There were 39 plants per replicate that amounted to 117 plants per treatment.

At RCRS, the inert substrates (chipping 3/8, rocksand 2 mm and rocksand 4 mm) were evaluated singly. Organic substrates like scum, flyash and poultry litter were used in combination with soil. The poultry litter used was composted prior to mixing. Sawdust was obtained from the furniture industry and was mixed with manure and soil to compensate for its high C: N ratio. It is to be noted that the mixture bagasse: manure: soil (1:1:1) is commonly used for the production of anthuriums.

At WCRS, the mixture bagasse: manure: soil (1:1:1) was also used as a control. In the other treatments under study, bagasse was replaced by the organic and inert substrates in the same ratio as shown in Table 1.

<table>
<thead>
<tr>
<th>Réduit CRS</th>
<th>Ratio</th>
<th>Wooton CRS</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawdust</td>
<td>Manure   : Soil</td>
<td>1:1:1</td>
<td>Sawdust</td>
</tr>
<tr>
<td>Biogases</td>
<td>Manure : Soil</td>
<td>1:1:1</td>
<td>Bagasse</td>
</tr>
<tr>
<td>Scum</td>
<td>: Soil</td>
<td>1:1</td>
<td>Scum</td>
</tr>
<tr>
<td>Flyash</td>
<td>: Soil</td>
<td>1:1</td>
<td>Flyash</td>
</tr>
<tr>
<td>Poultry Litter</td>
<td>: Soil</td>
<td>1:1</td>
<td>Poultry Litter</td>
</tr>
<tr>
<td>Chipping 3/8</td>
<td>: Soil</td>
<td>1:1</td>
<td>Chipping 3/8</td>
</tr>
<tr>
<td>Rocksand 2 mm</td>
<td>: Manure : Soil</td>
<td>1:1:1</td>
<td>Rocksand 2 mm</td>
</tr>
<tr>
<td>Rocksand 4 mm</td>
<td>: Manure : Soil</td>
<td>1:1:1</td>
<td>Rocksand 4 mm</td>
</tr>
</tbody>
</table>

All mixing was done on a volume basis. Samples of all substrates were taken from the planting beds and sent to the Agricultural Chemistry Division for analysis of pH, E.C., total N %, available P and K and percentage of organic carbon.

The planting material used was tissue-cultured plantlets of variety Ozaki. Fertilization was carried out on a weekly basis by alternating with Vegeflor 12:4:8 and Vegeflor 14.5:14.5:14.5 (Table 2). Vegeflor 14.5:14.5:14.5 is a soluble fertilizer formulated for application as a foliar feed in anthurium culture and the rate of application is 3g / litre of water. Vegeflor 12:4:8 is a granular fertilizer especially formulated for anthurium cultivation and the rate of application is 32 – 40 kg per acre per month.

The trial at RCRS was irrigated using the drip irrigation system and the trial at WCRS was rain fed. However water was applied during the drought prevailing in 1999. The main pests encountered were thrips and mites and they were controlled by alternate sprayings of dicarzol, mesurol and selecron.

The study was set up at RCRS in March 1998 and at WCRS in July 1998. Data collection started after six months upon establishment of the plants. At RCRS data were collected on a weekly basis from
August 1998 to August 1999 whereas at WCRS data were collected from January 1999 to January 2000.

Table 2 % Composition of fertilizers used for the study.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Vegeflor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12:4:8</td>
</tr>
<tr>
<td>1 Total Nitrogen</td>
<td></td>
</tr>
<tr>
<td>2 Nitrate</td>
<td>11</td>
</tr>
<tr>
<td>3 Ammonic</td>
<td>1</td>
</tr>
<tr>
<td>4 Organic</td>
<td>-</td>
</tr>
<tr>
<td>5 Phosphate</td>
<td>P2O5</td>
</tr>
<tr>
<td>6 Potash</td>
<td>K2O</td>
</tr>
<tr>
<td>7 Soluble Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>8 Calcium</td>
<td>CaO</td>
</tr>
<tr>
<td>9 Sulphur</td>
<td>S</td>
</tr>
<tr>
<td>10 Magnesium</td>
<td>MgO</td>
</tr>
<tr>
<td>11 Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>12 Manganese</td>
<td>Mn</td>
</tr>
<tr>
<td>13 Boron</td>
<td>B2</td>
</tr>
<tr>
<td>14 Zinc</td>
<td>Zn</td>
</tr>
<tr>
<td>15 Cobalt</td>
<td>Co</td>
</tr>
<tr>
<td>16 Molybdenum</td>
<td>Mo</td>
</tr>
<tr>
<td>17 Chloride content</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

The parameters measured at each harvest included the number of surviving plants, the total flower production, the maximum length and width of spathe, the spathe colour, the spadix diameter (using a vernier calliper), the length and colour of spadix and length of flower stem. The area of the flower was calculated using the product of length and width of spathe (Higaki T. et al. 1985(a), 1985(b)). Colour of spathe was measured on a scale of 1 to 5 from the palest to the darkest. The most colourful flower (brightest red) was given a score of three.

RESULTS AND DISCUSSION

Table 3 Results of sample analysis from Réduit CRS

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Ratio</th>
<th>PH</th>
<th>EC at 25°C - μS</th>
<th>Total N %</th>
<th>Available P ppm</th>
<th>Available K me %</th>
<th>OC* %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawdust: Manure: Soil</td>
<td>1:1:1</td>
<td>7.3</td>
<td>679.0</td>
<td>0.35</td>
<td>1 360</td>
<td>8.25</td>
<td>6.70</td>
</tr>
<tr>
<td>Bagasse: Manure: Soil</td>
<td>1:1:1</td>
<td>7.3</td>
<td>315.0</td>
<td>0.61</td>
<td>1 830</td>
<td>6.78</td>
<td>5.71</td>
</tr>
<tr>
<td>Scum : Soil</td>
<td>1:1</td>
<td>7.0</td>
<td>300.0</td>
<td>0.79</td>
<td>2 139</td>
<td>4.72</td>
<td>7.03</td>
</tr>
<tr>
<td>Flyash : Soil</td>
<td>1:1</td>
<td>7.2</td>
<td>179.5</td>
<td>0.26</td>
<td>1 768</td>
<td>11.50</td>
<td>5.46</td>
</tr>
<tr>
<td>Poultry Litter : Soil</td>
<td>1:1</td>
<td>7.6</td>
<td>1 116.0</td>
<td>0.70</td>
<td>2 152</td>
<td>12.38</td>
<td>4.96</td>
</tr>
<tr>
<td>Chipping 3 / 8</td>
<td>6.3</td>
<td>59.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocksand 2 mm</td>
<td>6.4</td>
<td>45.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocksand 4 mm</td>
<td>6.2</td>
<td>59.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*OC = Organic carbon
It is important to maintain the pH of the substrate between 5.3 and 6.3 to ensure availability of microelements like iron, manganese, zinc, boron, copper and molybdenum. The ideal pH for cultivation of anthurium is 5.7 (Ing. Lont A. 1994). Analysis of samples under study is given in Tables 3 and 4 and although the pH was higher for all substrates used in different combinations than those recommended, no deficiency symptoms were recorded. Organic substrates used were also higher in nutrient content as compared to the inert substrates. The level of phosphorus in poultry litter was the highest among all the substrates evaluated. However it is to be noted that the composition of the medium was not considered prior to fertilization and the same fertilization was used for all substrates on both stations.

Table 5 gives the results of data collected at RCRS. The statistical analysis shows that no significant difference was obtained for the number of plants which survived in each treatment. This shows that the plants could grow equally well in all these substrates. As for parameters like flower production, size of flower, length and diameter of spadix, length of flower stem, there were significant differences between substrates. The flower production was lower and flowers were smaller for plants growing in inert substrates (chipping 3/8, rocksand 2 mm and rocksand 4 mm). The inability of these media to retain
water was also noted. However good root development and cleaner roots were noted. A better root anchorage was observed in the inert substrates.

Higher flower production was noted in mixtures of bagasse : manure : soil and sawdust : manure : soil followed by scum : manure : soil and flyash : manure : soil. Larger flower sizes were obtained in mixtures of scum : soil and sawdust : manure : soil followed by bagasse : manure : soil and flyash : soil. The same was observed for the length and diameter of the spadix. As for mixtures of poultry litter : soil, lower values were obtained for these parameters. From data taken on spathe colour, it was noted that the plants growing in scum : soil, sawdust : manure : soil, bagasse : manure : soil and flyash : soil gave higher percentages of bright flowers (score 3) compared to the other substrates. The same observation was made for spadix colour whereby the plants growing in scum : soil, sawdust : manure : soil, bagasse : manure : soil and flyash : soil gave spadices with regular red colour and whitish base compared to plants grown in the other substrates. The advantage of the organic substrates was that they had excellent water retention capacity. Their disadvantage is that they undergo decomposition and the highest decomposition rate was observed in the mixture bagasse : manure : soil and composted poultry litter : soil as opposed to scum : soil, flyash : soil and sawdust : manure : soil. The major problem noted with the mixtures scum : soil and flyash : soil is that they have a tendency to settle and compact. The mixture sawdust : manure : soil has a slower decomposition rate and it provides better drainage and good aeration for the roots.

As shown in Table 6 there was no significant difference for number of plants that survived in each substrate. This shows good adaptation of plants in these substrates. Flower production was significantly higher in the mixture rocksand 4 mm : manure : soil, chipping 3/8 : manure : soil, sawdust : manure : soil and bagasse : manure : soil and the lowest flower production was noted in the mixture flyash : manure : soil. Larger flower sizes were recorded for the mixtures rocksand 2 mm : manure : soil and rocksand 4 mm : manure : soil, chipping 3/8 : manure : soil, poultry litter : manure : soil, and bagasse : manure : soil. The length of the spadix and length of the flower stalk was also significantly higher in these substrates as compared to the mixtures scum : manure : soil and flyash : manure : soil. Significant differences were noted for diameter of spadix; however very few abortive spadices were recorded at Wooton CRS as compared to Réduit CRS. Good drainage was recorded for inert substrates used in combination with manure and soil. Spadices with regular red colour and whitish bases were recorded for plants grown in rocksand 2 mm : manure : soil, rocksand 4 mm : manure : soil, chipping 3/8 : manure : soil, sawdust : manure : soil and bagasse : manure : soil. As for spathe colour, it was noted that the plants growing in rocksand 4 mm : manure : soil, chipping 3/8 : manure : soil, sawdust : manure : soil and bagasse : manure : soil. As for spathe colour, it was noted that the plants growing in rocksand 4 mm : manure : soil, chipping 3/8 : manure : soil, sawdust : manure : soil and bagasse : manure : soil.

### Table 6 Average values of the parameters measured at Wooton CRS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ratio</th>
<th>Number of plants</th>
<th>Flowers / plant</th>
<th>Area of flower</th>
<th>Length of spadix</th>
<th>Diameter of spadix</th>
<th>Length of flower stalk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawdust : Manure : Soil</td>
<td>1:1:1</td>
<td>38.5</td>
<td>4.40</td>
<td>35.5</td>
<td>3.69</td>
<td>5.80</td>
<td>24.5</td>
</tr>
<tr>
<td>Bagasse : Manure : Soil</td>
<td>1:1:1</td>
<td>36.8</td>
<td>4.28&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>41.8&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.33&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.18&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>27.4&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Scum : Manure : Soil</td>
<td>1:1:1</td>
<td>36.3</td>
<td>3.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>8.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.92&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>24.4&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Flyash : Manure : Soil</td>
<td>1:1:1</td>
<td>34.7</td>
<td>1.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.92&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>5.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.4</td>
</tr>
<tr>
<td>Poultry Litter : Manure : Soil</td>
<td>1:1:1</td>
<td>36.5</td>
<td>3.67&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>39.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.93&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>5.91&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>24.2&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chipping : Manure : Soil</td>
<td>1:1:1</td>
<td>36.7</td>
<td>4.91&lt;sup&gt;d&lt;/sup&gt;</td>
<td>43.2&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.29&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.41&lt;sup&gt;d&lt;/sup&gt;</td>
<td>26.0&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rocksand 2 mm : Manure : Soil</td>
<td>1:1:1</td>
<td>36.5</td>
<td>3.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>39.6&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.04&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>6.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>25.4&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rocksand 4 mm : Manure : Soil</td>
<td>1:1:1</td>
<td>37.9</td>
<td>4.37&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>45.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.32&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.40&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>28.1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>S.E. ±</td>
<td></td>
<td>0.9</td>
<td>0.44</td>
<td>1.88</td>
<td>0.14</td>
<td>0.19</td>
<td>0.83</td>
</tr>
<tr>
<td>P ≤ 0.05</td>
<td></td>
<td>NS</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* Significant difference
Alternate substrates for anthurium production  

Rita Nowbuth


manure : soil and bagasse : manure : soil gave the higher percentages of bright flowers (score 3) as compared to the other substrates. A higher level of decomposition was noted for mixtures of bagasse : manure : soil and poultry litter : manure : soil. Among the organic substrates, the mixture flyash : manure : soil gave very poor performance for all parameters recorded. In superhumid regions like Wooton CRS, plants have shown that they adapt better in substrates which have a good drainage capacity.

CONCLUSION

The substrate evaluation study shows that inert materials have good characteristics that can be exploited for use as a growing medium. The low performance of these materials when used singly could be associated with the type of fertilization used. This observation was made from trials on hydroponics which have been carried out using these substrates and soluble fertilizers. It is therefore advisable to use soluble fertilizers rather than granular fertilizers when inert substrates are used singly. The good performance of these substrates when used in combination with manure and soil at WCRS indicates their potential use as medium in the superhumid zone. The main advantages of these inert substrates are that they provide good root penetration, good drainage and aeration to the roots and that they do not decompose. As for organic substrates under study, the mixture sawdust : manure : soil appears to be the most promising one. The mixture bagasse : manure : soil, which is commonly used for anthurium production, confirms its good potential both at RCRS and WCRS. The tendency of the mixtures scum : soil and flyash : soil to settle and compact make them very poor alternatives especially in regions with high rainfall. As for poultry litter mixed with manure and soil, it gave good results at WCRS but its main disadvantage is that it decomposes very quickly.

REFERENCES


**CROP CYCLE STUDY IN PINEAPPLE: PRELIMINARY RESULTS**

*R A Bhugaloo*

Agricultural Research and Extension Unit

**ABSTRACT**

Monthly planting of 3 sucker sizes (200 - 250 g, 250 - 300 g, 300 - 350 g) of pineapple, cv Victoria, was carried out at three sites in planters' fields, followed by 5 flower induction times (5, 6, 7, 8, and 9 months after planting). The objective was to find the effect of the 15 treatments on the harvest time, yield and quality of pineapple. The results over 12 months of planting show that irrespective of sucker size and time interval from planting to floral induction, the crop cycle was lengthened by around 40 days when floral induction was carried out in winter compared to summer. Total yield was significantly higher when sucker size was above 250 g while fruit weight was increased significantly as the sucker size and the time interval to floral induction increased. The ratio of crown to fruit length tended to decrease with increase in fruit weight while ° brix was not influenced by sucker size and flower induction time.

**Keywords:** *Ananas comosus*, crop cycle, crown, flower induction, fruit, pineapple, sucker, yield.

**INTRODUCTION**

Pineapple, *Ananas comosus* (L) Merr., is the second main horticultural crop exported from Mauritius after anthurium. The volume exported during the last five years has gradually increased from 242 tonnes to 645 tonnes in 1999. In order for Mauritius to maintain and increase the volume of export, supply of pineapple on the European market should be effected during the festive period; i.e. in December and during Easter. Furthermore, the fruits should satisfy the market norms in terms of fruit size, fruit to crown ratio, colour of shell, brix, acidity and phytosanitary conditions. There are three main zones of pineapple production in Mauritius, namely: Montagne Longue, Camp de Masque and Riche en Eau. In order for the three zones to produce quality pineapple at the required periods, a proper planning of planting dates combined with appropriate flower induction times is essential. The mean weight of the fruit depends on the plant development at the time of flower induction (Py et al. 1987). Moreover, since the fruit size is dependent primarily on the mass of the propagule (Nakasone et al. 1999), the sucker size used at planting will determine the fruit size at harvest. On-farm trials were set up in the three production zones in order to determine the optimum planting time, size of sucker and flower induction time combinations to produce fruits of export quality at targeted periods.

**MATERIALS AND METHODS**

The experiment was carried out with cv. Queen Victoria at three sites: Ville Noire (altitude, 20m), Congomah / Camp La Boue (altitude, 131 m), and Camp de Masque Pavé (altitude, 165m). The treatments included three sucker sizes (200 - 250 g (S1), 250 - 300 g (S2), 300 - 350 g (S3)) and five flower induction times ( 5 (F1), 6 (F2), 7 (F3), 8 (F4) and 9 (F5) months after planting). Plantations were effected on a monthly basis in 1998, from January to December at Ville Noire, from February to December at Congomah / Camp La Boue and from March to December at Camp de Masque. The design used was a randomised complete block with 2 replicates. The experimental plot at the three sites contained 200 plants. At Ville Noire, the plot size was 450 m², with 4 rows of plants at a spacing of 20 x 20 cm (density of 133 000 plants ha⁻¹). At Congomah / Camp La Boue and Camp de Masque Pavé, the plot size was 603 m² with 3 rows of plants spaced at 30 cm between rows and 20 cm within rows (density 100 000 plants ha⁻¹). Plantations at Ville Noire were
Crop cycle study in pineapple  Preliminary results  R A Bhugaloo

effected using plastic mulch, while at the other 2 sites, no mulch was used. Suckers used as planting material for all sites were taken from the nursery of Tropical Bliss Ltd, at Ville Noire.

Fertilisers (urea and solupotash) were applied in liquid form using a sprayer throughout the whole crop cycle. For a population density of 100 000 plants ha\(^{-1}\), a constant dose of urea at the rate of 150 kg per hectare and solupotash at the rate of 215 kg per hectare was split seven times. At Ville Noire (population density of 133 000 plants ha\(^{-1}\)), a proportionate amount of urea and solupotash was applied. The first two applications were applied in solid form before placing the mulch and the five remaining doses were foliar applied. Flower induction treatments were performed 15 days after the last fertilisation using Ethrel at the rate of 3.9 l ha\(^{-1}\) and Urea at the rate of 65 kg ha\(^{-1}\) in 2600 litres of water for a population density of 100 000 plants per hectare. For Ville Noire, the application was adjusted proportional to number of plants. The aqueous solution was sprayed on the whole foliage with a sprayer. The cultural practices were maintained as for commercial crops. In addition to the measurement of total yield, 10 fruits were randomly selected from each plot at all the sites and the following parameters were measured: fruit length, fruit weight, crown length, \(^\circ\)Brix, and the incidence of infection of Fruitlet Core Rot (FCR).

RESULTS AND DISCUSSION

Crop Cycle Length

The crop cycle length varied between 143 and 186 days at Congomah / Camp la Boue, 148 and 186 days at Camp de Masque Pavé and 142 and 181 days at Ville Noire. At all three sites, the crop cycle was lengthened by 40 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, growth was accelerated during summer (Bartholomew and Malézieux,1994). Fruits harvested in early April (Easter ) at the three sites, were the result of floral induction treatments effected in mid-November. It was also observed that for harvests at the end of December, floral induction was carried out at the end of June for Camp de Masque Pavé and Congomah / Camp La Boue and during the 3\(^{rd}\) week of July for Ville Noire. For a better estimate of floral induction time for a harvest targeted for early April and end of December, a larger set of observations are required at the 3 sites.

Yield

A significant difference was observed on total yield at the three sites when sucker weight was above 250g (Table 1). The total yield at Ville Noire was significantly higher (73.6 - 81.2 tonnes ha\(^{-1}\)) when compared to the other 2 sites (44.1 - 52.7 tonnes ha\(^{-1}\)). Similarly, the average fruit weight at Ville Noire was around 30 % heavier than that at the other 2 sites. The higher yield was attributed to a higher planting density (4 rows per bed compared to 3 rows) while the larger fruits resulted from the positive influence of plastic mulch on growth rate through moisture conservation and an increased soil temperature (Ekern,1967).

<table>
<thead>
<tr>
<th>Site</th>
<th>Camp de Masque Pavé</th>
<th>Congomah / Camp la Boue</th>
<th>Ville Noire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucker size</td>
<td>S1      S2      S3</td>
<td>S1      S2      S3</td>
<td>S1      S2  S3</td>
</tr>
<tr>
<td>Total yield t ha(^{-1})</td>
<td>44.1  47.2  49.4</td>
<td>45.3  50.1  52.7</td>
<td>73.6  78.1  81.2</td>
</tr>
<tr>
<td>Average fruit weight g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FIT(^*)</td>
<td>5       438  421  443</td>
<td>362  457  454</td>
<td>606  642  699</td>
</tr>
<tr>
<td></td>
<td>6       421  452  425</td>
<td>420  452  507</td>
<td>621  653  714</td>
</tr>
<tr>
<td></td>
<td>7       453  462  495</td>
<td>471  501  547</td>
<td>692  728  729</td>
</tr>
<tr>
<td></td>
<td>8       471  515  649</td>
<td>504  533  550</td>
<td>665  750  727</td>
</tr>
<tr>
<td></td>
<td>9       478  531  513</td>
<td>506  560  577</td>
<td>692  686  736</td>
</tr>
</tbody>
</table>

*FIT: Floral Induction Time
Sucker size of 200 - 250 g at Camp de Masque Pavé and Camp La Boue, with a flower induction time of less than 7 months after planting, produced small fruits of size less than 450 g, qualifying only for a niche market of baby pines. Similar small fruits were obtained at Camp de Masque Pavé, when floral induction was carried out only 5 months after planting using suckers above 250 g. The highest demand on the export market is for fruits of calibre 7 and 8 (650 to 900 g). At Camp de Masque Pavé and Congomah / Camp La Boue, none of the fruits were found in this category. These can be exported under calibre 9 (450 - 650 g). At Ville Noire, if floral induction is carried out before 7 months for sucker weights of 200 - 250 g, the fruits produced can be marketed under calibre 9 only. Similar fruits are obtained, if suckers 250 - 300 g are induced only 5 months after planting, otherwise, all the fruits of Ville Noire satisfy the calibre 8.

Lower fruit weights from suckers of 300 - 350 g with floral inductions carried out at 9 months at Camp de Masque Pavé, may be attributed to natural flowering. Therefore, for sucker weights above 300 g, flower induction should not be carried out after 8 months post-planting. Similarly, at Ville Noire, floral induction on suckers of 250 - 300 g and 300 - 350 g should be avoided after 8 months and 9 months respectively.

**Fruit Quality**

The fruit length to crown length ratio of 1:1, as required for export was not satisfied at the three sites. **Table 2** shows that there was a significant difference on crown length among the 3 sites, the fruits at Ville Noire bearing the longest crowns, followed by Congomah / Camp La Boue and Camp de Masque Pavé. The fruit length to crown length ratio was higher at Camp de Masque Pavé, followed by Congomah / Camp La Boue and Ville Noire. Trends indicated that on sites where fruits were bigger, the crowns were also longer. However, it was noticed that with increasing sucker size, the ratio of fruit to crown length tended to increase. Also, as the induction time increased from 5 to 9 months, the crown length to fruit length ratio decreased.

**Table 2** Effect of sucker weight on fruit quality

<table>
<thead>
<tr>
<th>Site</th>
<th>Camp de Masque Pavé</th>
<th>Congomah / Camp La Boue</th>
<th>Ville Noire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucker Size</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
</tr>
<tr>
<td>Crown length cm</td>
<td>13.5</td>
<td>13.4</td>
<td>13.2</td>
</tr>
<tr>
<td>Fruit: crown</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Brix</td>
<td>14.3</td>
<td>14.3</td>
<td>14.4</td>
</tr>
<tr>
<td>Fruitlet core rot %</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
</tr>
</tbody>
</table>

**Brix**

The brix was above 13.9 for all the 3 sites and irrespective of sucker size, planting date and flower induction times. The results, however, show that the fruits at Camp La Boue, were consistently sweeter than those at Ville Noire and Camp de Masque Pavé. Observations over 2 more years are needed to evaluate this tendency.

**Fruitlet Core Rot**

During the experimental period, the incidence of fruitlet core rot peaked to a maximum (3.1, 3.5 and 3.6 % at Camp de Masque Pavé, Congomah / Camp La Boue and Ville Noire respectively), when flower induction was carried out 6 weeks after planting. The incidence showed an increase with increase in sucker weight at Camp de Masque Pavé and Congomah / Camp La Boue. Since the level of fruitlet core rot infestation is controlled by climatic factors (Mourichon et al. 1987), observations over two more years can provide a better indication on its relationship with site, sucker size and floral induction time.
CONCLUSION

The preliminary results of the crop cycle study carried out at the three main zones of pineapple production in Mauritius showed that total yield and unit fruit weight were higher (40% and 30% respectively) at Ville Noire than at the other two sites. At all the three sites, the crop cycle length was around 40 days longer when flower induction was carried out in winter. At Camp de Masque Pavé, floral induction should not be carried out earlier than 6 months after planting in order to avoid small fruits (less than 450g). Floral induction can start as from 6 months after planting for suckers weighing more than 250g and suckers weighing more than 300g should be induced before 9 months after planting in order to avoid natural flowering.

At Congomah / Camp La Boue, suckers of 200 - 250g can be induced as from 7 months, while those of more than 250g can be inducted as from 5 months. At Ville Noire, suckers of 250 - 300g should not be induced after 8 months after planting and those of 300 - 350g, not after 7 months in order to avoid natural flowering. Crown to fruit length was excessive at the three sites and had a tendency to decrease with increase in fruit length. The brix was satisfactory at all sites and incidence of fruitlet core rot could be influenced by fruit size. These results should be consolidated with observations from 2 additional years.

ACKNOWLEDGEMENTS

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A STUDY OF THE PROSPECTS AND POTENTIAL OF LATE PRODUCTION OF ONION IN THE REGION OF LA MARIE

S Seetohul P Hanoomanjee and R Vencatasamy
Agricultural Research and Extension Unit

ABSTRACT

Onion is an important vegetable cash crop in Mauritius. It is grown mainly for local consumption. The local production of onion is highly seasonal with the bulk of the crop harvested around October to November. This results in a seasonal surplus production of 1600 to 1800 tonnes annually.

The present experiments were carried out in order to study the performance of the onion crop at 3 planting dates namely the 28th May, the 16th June, and the 17th July 1999 under 3 different water regimes namely, 0.5 ET\text{crop} (I_1), 1.0 ET\text{crop} (I_2) and 1.5 ET\text{crop} (I_3) compared to the rainfed crop (I_0). The experiment was implemented in a planter’s field at La Marie.

A significant increase in the marketable bulb yield from 50.6 to 90.5 t ha\(^{-1}\) (for the first planting date), from 25.0 to 62 t ha\(^{-1}\) (for the second planting date) and from 13 to 23.4 t ha\(^{-1}\) (for the third planting date) was observed with increasing water regimes from the rainfed situation (I_0) to 1.5 ET\text{crop} (I_3).

With a delay in planting date from the 28th of May (PD1) to the 17th of July 99 (PD3), a significant drop in yield from 89.6 to 20.8 t ha\(^{-1}\) (for the 0.5 ET\text{crop} regime), from 88.3 to 24.2 t ha\(^{-1}\) (for the 1.0 ET\text{crop} regime) and from 90.5 to 23.4 t ha\(^{-1}\) (for the 1.5 ET\text{crop} regime) was observed. This represented a 74 % decrease in yield on the average.

The most suitable water regimes throughout the crop cycle for optimum crop yields were 263, 385 and 328 mm for the 3 respective planting dates. The highest crop water supply was required at the bulbing phase which starts at 2 to 2½ months after transplantation. When bulbification is delayed in the summer months, a high water supply of 40 to 60 mm was required weekly.

Keywords: Onion, late production, water regimes, planting dates

INTRODUCTION

Onion is an important vegetable cash crop in Mauritius. It is grown mainly for the fresh market consumption and for storage. The local demand has been increasing over the last few years and is presently of the order of 10 000 tonnes annually. This is met partly by the local production which is around 6 000 tonnes annually and partly by imports. The gross annual market value of our production amounts to MUR 60 million approximately.

Onion production in Mauritius is highly seasonal with the bulk of the crop harvested around October to November. This results in a seasonal surplus production. About 1 600 to 1 800 tonnes of onion are purchased by the Agricultural Marketing Board from the local producers for storage under refrigerated conditions. This stock is released for sale by the AMB in periods of shortage and furthermore, each year onion is imported by the AMB as from February till July in order to meet the local requirements.

During the technological review workshops and other interactive meetings between the research and extension staff of AREU and the onion growers of La Marie / Glen Park, the lack of irrigation facilities was identified as a serious constraint to the conduct of late production of onions in the month of late December / early January.

The aim of this experiment is to study the prospects of producing high quality onions in the late season in the region of La Marie. If onions could be produced during that period, they could be cured and stored by the farmers for sale as from February, a period when the country depends on imported onions to satisfy the local requirements. This would further assist in reducing the storage costs and losses incurred by the surplus crop produced during the peak harvest season of October to November.

The experiment was implemented with the following objectives:

To study the performance of the onion crop at 3 planting dates namely the 28th of May, the 16th of June, and the 17th of July 1999 under drip irrigation.

To study the performance of the onion crop under 3 different water regimes namely, 0.5 ET\text{crop} (I_1), 1.0 ET\text{crop} (I_2) and 1.5 ET\text{crop} (I_3) compared to the rainfed crop (I_0).
MATERIALS AND METHODS

The project was implemented in a planter’s field at La Marie. The trial design was a split plot with 3 replicates. The 3 planting dates were tested in the main plots and the 4 water regimes in the sub plots. Sowing was performed on 3 dates namely, the 28th of May, 16th of June and the 17th of July 1999. Onion seeds of the cultivar Sivan were sown on raised beds at the rate of 10 g m⁻². Experimental plots consisted of raised beds one metre wide and 30 m long. Manure was broadcasted at the rate of 2.5 kg m⁻². The complex fertilizer 13:13:20:2 was applied at the rate of 60 g m⁻² on the beds on the day of transplanting.

Onion seedlings were transplanted when they reached the 3 - 4 leaf stage which was attained at a plant height of 15 - 20 cm. The seedlings for the 3 sowing dates were transplanted on the 23rd of July, the 3rd of September and the 22nd of September 1999 respectively. Seedlings were transplanted at the spacing of 15 x 10 cm.

The 4 water regimes were as follows: 0.5ETcrop(I₁), 1.0 ETcrop (I₂), 1.5 ETcrop (I₃) and rainfed (I₀).

The amount of irrigation water to be applied was calculated from the formula:

\[ \text{Amount of irrigation (d) = (P.Sa) D / Ea,} \]

Where P.Sa = readily available soil water (m)
D = Root zone depth (m)
Ea = Application efficiency (which is 0.9 for drip irrigation systems)

The irrigation interval was calculated from the formula:

\[ \text{Irrigation interval (I) = (P.Sa) D / ET}_{\text{onion}} \]

Rainfall and evaporation data were taken from the National Meteorological Services on a weekly basis. These data were used to adjust the amount of water to be supplied under the different water regimes. The exact amount of water to be supplied to the experimental plots was controlled by volumetric valves that were operated weekly. Irrigation was stopped 15 days before the harvest when onion tops started to fall.

The onion bulbs were harvested when the tops began to break and fall, well before the complete drying of the foliage. The onion crop was pulled by hand and arranged into windrows so that the bulbs were partly covered by the tops and hence were protected from sunscalding damage. After a field curing period of 3 to 7 days, the tops were fairly well dried down; they were cut off using knives and scissors, at a length of 3 to 4 cm away from the bulbs. The roots were also trimmed.

Onion bulbs were then thoroughly cured in a solar curing unit for 7 to 10 days.

Onion bulbs were then graded into three categories according to size, namely category 1 (≤ 4cm), Category 2 (4 ≤ Diameter < 7cm) and Category 3 (≥ 7cm).

RESULTS AND DISCUSSION

The irrigation water requirement was supplied at the 3 water regimes under test namely, 0.5 ETcrop, 1.0 ETcrop and 1.5 ETcrop, taking into consideration the calculated crop evaporation rate, the crop development stage, the plant rooting depth and the weekly precipitation rate.

The total amount of water (in mm) supplied to the crop throughout the whole crop cycle for each planting date under the 3 respective water regimes (I₁, I₂, I₃ ) and the rainfed regime (I₀ ) is illustrated in Table 1.

It should be observed that the total amount of water supplied to the crop is composed of 2 fractions namely the amount derived from rainfall and the amount supplemented by drip irrigation. The performance of the onion crop cultivar Sivan at the 3 planting dates and 4 water regimes in terms of the marketable onion bulb yield is shown Table 2.
A study of the prospects and potential of late production of onion in the region of La Marie. P. Hanoomanjee et al.

Table 1 Total amount of water (mm) supplied to the crop under different water regimes and planting dates

<table>
<thead>
<tr>
<th>Planting dates</th>
<th>Rainfall</th>
<th>Water from drip irrigation</th>
<th>Total amount of water received</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀</td>
<td>I₁</td>
<td>I₂</td>
</tr>
<tr>
<td>1</td>
<td>1 207</td>
<td>56 125 194 263 332 401</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>84 76</td>
<td>186 301 160 270 385</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>104 81</td>
<td>224 359 185 328 463</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2 Marketable onion bulb yield of onion cultivar Sivan at different planting dates and water regimes

<table>
<thead>
<tr>
<th>Irrigation Regimes</th>
<th>Marketable bulb yield t ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planting dates</td>
</tr>
<tr>
<td></td>
<td>1 2 3 Average</td>
</tr>
<tr>
<td>I₀</td>
<td>50.60 25.00 13.00 29.53</td>
</tr>
<tr>
<td>I₁</td>
<td>89.60 39.90 20.80 50.10</td>
</tr>
<tr>
<td>I₂</td>
<td>88.30 45.30 24.20 52.60</td>
</tr>
<tr>
<td>I₃</td>
<td>90.50 62.00 23.40 58.63</td>
</tr>
<tr>
<td>Average yield</td>
<td>79.70 43.00 20.30</td>
</tr>
<tr>
<td>S.E ±</td>
<td>4.39 2.59 1.21</td>
</tr>
</tbody>
</table>

A significant increase in the marketable bulb yield from 50.6 to 90.5 t ha⁻¹ (for the first planting date), from 25 to 62 t ha⁻¹ (for the second planting date) and from 13 to 23.4 t ha⁻¹ (for the third planting date) was observed with increasing water regimes from the rainfed situation (I₀) to 1.5 ET₉₀ (I₃).

With a delay in planting date from the 28th May (PD1) to the 17th July 99 (PD3), a significant drop in yield from 89.60 to 20.8 t ha⁻¹ (for the 0.5 ET₉₀ regime), from 88.3 to 24.2 t ha⁻¹ (for the 1.0 ET₉₀ regime) and from 90.5 to 23.4 t ha⁻¹ (for the 1.5 ET₉₀ regime) was observed. This represented a 74 percent decrease in yield on average.

The yield response with respect to increasing water regimes for each planting date is graphically represented in Figure 1.

It can be observed that for the 1st planting date, 263 mm of water was enough to produce a significant increase in marketable yield whereas, for the 2nd and 3rd planting dates, 385 mm and 328 mm of water were required to bring about any significant increase in bulb yield.

Any increase in water regimes beyond 263 mm, 385 mm, and 328 mm for the 3 respective planting dates did not contribute towards a significant increase in yield as indicated by the trend observed in Figure 1.

The water regimes namely 263, 385 and 328 mm that produced the highest bulb yields at the 3 different respective planting dates were compared with the 3 prevailing rainfed water regimes namely 207, 84 and 104 mm. It can be observed that the percentage of water deficit occurring in the three different situations were 27 %, 358 % and 215 % respectively.

The weekly rainfall distribution prevailing at the experimental site from the date of transplantation until crop maturity is graphically shown for each planting date under test (see Figures 2, 3 and 4). These were matched with the most suitable water regime for the three respective planting dates, that is 263 mm for planting date 1, 385 mm for planting date 2 and 328 mm for planting date 3.

It can be observed that in all three situations, the highest crop water supply was required at the bulbing phase which normally starts at 2 to 2 1/2 months after transplantation. This also indicates that under the rainfed water regimes, the highest water deficit occurred during the bulbing phase.
When bulbification is delayed to the summer months as in the 2nd and 3rd planting dates, a water supply of the order of 40 to 60 mm / week is required. If the bulbing phase occurs in late winter / early summer, a lower water supply of the order of 25 to 30 mm is required.

The harvested onion bulbs for the 3 planting dates and under the 4 water regimes were separated into 3 bulb sizes namely, small, medium, and large with bulb diameters of < 4 cm, 4 – 7 cm, and > 7 cm respectively. The harvested fraction belonging to each bulb size was expressed as a percentage of the total marketable yield for each planting date and water regime. The results are illustrated in Table 3 and Figure 5.
Figure 3  Distribution of the applied water regime (I3) and rainfall from the time of transplantation until crop maturity (planting date 2)

Figure 4  Distribution of the applied water regime (I2) and rainfall from the time of transplantation until crop maturity (planting date 3)

Table 3  Size distribution ( % total marketable yield ) of onion bulbs harvested from different planting dates and water regimes.

<table>
<thead>
<tr>
<th>Water Regimes</th>
<th>Planting date 1</th>
<th>Planting date 2</th>
<th>Planting date 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td>I0</td>
<td>6.05</td>
<td>40.14</td>
<td>53.81</td>
</tr>
<tr>
<td>I1</td>
<td>2.64</td>
<td>20.43</td>
<td>76.93</td>
</tr>
<tr>
<td>I2</td>
<td>1.57</td>
<td>9.53</td>
<td>88.90</td>
</tr>
<tr>
<td>I3</td>
<td>1.98</td>
<td>21.70</td>
<td>76.32</td>
</tr>
</tbody>
</table>
It was observed that a higher percentage of large bulbs, ranging from 53.81 to 76.32 %, was obtained from the crop produced at the 1st planting date compared to the 2nd and 3rd planting dates. No large bulbs were obtained at the 3rd planting date. The crops produced from the 2nd and 3rd planting dates contained a higher percentage of medium sized bulbs ranging from 74.62 to 88.6% for the irrigated treatments.

Considering the effect of water regimes on bulb size, it was observed that increasing water regimes tend to produce onion bulbs of bigger size irrespective of planting dates.

The shift in the onion planting date from the 28th May (the 1st planting date) to the 17th July 1999 (the 3rd planting date) has been observed to cause a reduction in the crop cycle from 175 days (23 weeks) to 151 days (21 weeks).

The mean daily temperatures and daylength prevailing throughout the experimental period were collected as secondary data from the Meteorological Services. These fluctuations were graphically represented from the month of May to December 1999 as shown in Figure 6. The 3 planting dates under test have been located and matched to the existing daylength and temperature fluctuations shown in Figure 6.

The mean daily temperatures and daylength prevailing throughout the experimental period were collected as secondary data from the Meteorological Services. These fluctuations were graphically represented from the month of May to December 1999 as shown in Figure 6. The 3 planting dates under test have been located and matched to the existing daylength and temperature fluctuations shown in Figure 6.

The vegetative crop development in onion is normally favoured by a period of short daylength coupled with low temperatures around 18 °C. The bulbing phase, on the other hand, is triggered by a period of increasing daylength coupled with increasing temperatures.

It can be seen that the crop raised from the 1st planting date benefited from a longer period of exposure to conditions of low temperatures and short daylengths resulting in a better and more vigorous vegetative growth and development when compared to the crops raised from the 2nd and 3rd planting dates. This has led to the best crop performance in terms of average marketable onion yield (79.70 t ha⁻¹) recorded over a crop cycle of 175 days (23 weeks) for the 1st planting date.

The crop raised from the 3rd planting date underwent a shorter and less vigorous vegetative phase resulting in a reduced average bulb yield of 20.3 t ha⁻¹ over a crop cycle of 151 days (21 weeks).

CONCLUSION

A significant increase in the marketable onion bulb yield was obtained with increasing water regimes from the rainfed situation to 1.5 ET crop.

With a delay in planting date from the 23rd May to the 17th July, a significant drop in yield was obtained irrespective of water regimes. This represented a 74 percent decrease in yield on the average. The sowing date can be delayed up to the 16th June when the average yield of 43 t ha⁻¹ was still profitable.

At the 3rd planting date, the average low yield of 20.3 t ha⁻¹ was not profitable taking into account that the estimated break even yield is 16 t ha⁻¹.

The most suitable water regimes for optimum crop yields were 263, 385 and 328 mm for the 3 respective planting dates.

The highest crop water supply was required at the bulbing phase which starts at 2 to 2½ months after transplantation. When bulbification is delayed to the summer months, a high water supply of 40 to 60 mm was required weekly. If the bulbing phase occurred in late winter / early summer; a lower water supply of 20 to 25 mm was required.

A high percentage of large bulbs (> 7 cm in diameter) was obtained from the crops produced at the first planting date. The onion crop produced at the 2nd planting date produced mostly medium sized bulbs of 4 to 7 cm in diameter.

Late production of onion in La Marie / Glen Park with the cultivar, Sivan is possible with a delayed sowing date of up to the 16th June coupled with an appropriate water regime of 385 mm. A yield of
about 42 t ha⁻¹ can be expected. Beyond the sowing date of 16th June, the yield potential of the crop is adversely affected even with adequate water supply. This is due to less favourable short day lengths and low temperature conditions which adversely affect the vegetative growth and development.

**Figure 5** Size distribution of onion bulbs harvested from different planting dates and water regimes

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Water regimes mm

- Small
- Medium
- Large

Planting date 1

- 207
- 263
- 332
- 410

Planting date 2

- 84
- 160
- 270
- 385

Planting date 3

- 104
- 185
- 328
- 463

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ACKNOWLEDGEMENTS

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We also extend our thanks to the Director of the Agricultural Research and Extension Unit for permission to publish the paper.

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ASSESSMENT OF THE CHLORIDE STATUS IN THE TOBACCO LEAF AND SOME POTENTIAL SOURCES FOR THE HIGH CHLORIDE LEVEL

Y. Cadersa and A. Atawoo
Agricultural Research and Extension Unit

ABSTRACT

High chloride level in tobacco has been a major concern to the tobacco industry at large. In order to address and investigate the problems of high chloride level in tobacco leaves, field trials were carried out over 3 growing seasons from March 1999 to August 2000. Fourteen sites were chosen representing major tobacco growing areas with different soil types and climatic conditions.

Results indicated that in all the regions, the chloride level in the leaves exceeded the threshold level of 1.5%. The chloride level was highest in lower primings and diminished with successive primings except for a slight increase in the tips. Leaf lamina had a lower chloride content than the midrib. There were significant variations in the leaf chloride content grown in the different areas.

Leaf collected from the different localities did not differ significantly in their nicotine content, which averaged 2.1 ± 0.22. Soil chloride content did not exceed the accepted norm level of 100 ppm. No relationship was found between either soil chloride or soil pH and leaf chloride level. Three areas were identified where tobacco could be produced with minimal chloride level (1.0 - 2.0).

Keywords: Tobacco, chloride, nicotine, leaf lamina, midrib.

INTRODUCTION

The tobacco leaf is composed of 85-90% water, mineral matter and organic compounds. The latter may be divided into organic acids, carbohydrates and alkaloids (Provost, 1959). Among the mineral nutrients, chlorine is recognized as an essential micronutrient in tobacco cultivation. When required in small amounts, it improves yield and certain quality factors such as colour, moisture content, elasticity, burning and keeping quality of tobacco leaves (Mc Evoy, 1957). However, larger amount of chloride have many adverse effects on the quality of tobacco so much so that the chloride content in tobacco leaves is considered as a major factor determining the quality of tobacco. Excess level of chlorine produces among others, leaves with the following characteristics:

- Poor burning capacity
- Muddy appearance and undesirable odour
- Highly hygroscopic, causing discoloration during storage
- Dull and dirty with a greyish tinge on the back surface (two-faced tobacco)

The threshold value for chloride in a good and acceptable tobacco leaf is usually set at below 1.5% (Chari, 1995). If the chloride content rises above 2.5%, the resulting tobacco is nearly incombustible (Akehurst, 1981).

The chloride content in the locally grown tobacco is generally high. Leaf analysis carried out in 1985 with the flue-cured variety Speight G28 showed a chloride content in the range of 2.08% to 3.72% in the leaf lamina and between 4.28% to 5.68% in the midrib (Ramahotar, 1990). Despite the fact that the chloride-free complex fertilizer (6:18:24) is recommended and used in tobacco cultivation, high level of chloride in the leaves has been a real problem and may be attributed to factors other than fertilization such as soil pH, rain or irrigation water.

This paper presents the results of investigations carried out on the flue-cured variety RG 13 in the major tobacco growing areas to determine the factors influencing the uptake and mobilization of
chloride in tobacco that could lead to a high chloride content in the cured leaves. Since inhibition of chloride uptake is rather difficult, an attempt has been made to identify growing areas where the problem could be minimal.

MATERIALS AND METHODS

The experiment was carried out in the first and second seasons of 1999 (February - December) and in the first season of 2000 (February-May) for the Virginia flue-cured tobacco variety RG13. Field trials were set up at fourteen sites representative of the major tobacco growing regions (Figure 1).

![Figure 1 Location of field trials](image)

At each locality, a tobacco field of around 0.5 ha representative of the area was chosen. In all cases, the fields were previously under sugar cane cultivation either belonging to individual planters or to sugar estates. Land was mechanically prepared using a disc-plough and rotovator at a depth of 30 cm. Tobacco furrows 40 cm wide and 30 cm deep were made using a pneumatic tractor.

Prior to field transplantation of tobacco seedlings, three composite soil samples, each constituted from 10 sub samples were taken at depth of 0-25 cm and 26-40 cm. In addition, soil samples from other tobacco growing regions namely Panchavati, Melrose, Camp Ithier, Valetta, Etoile, Schoenfield and Sans Souci were also collected.

The tobacco crops were managed by the planters themselves. At planting, the complex fertilizer (6:18:24) was applied at the recommended rate of 700 kg ha⁻¹ and was covered lightly with 5 cm of soil. Tobacco seedlings were transplanted at a spacing of 100 cm x 60 cm. Cultural practices such as weeding, earthing up, pest and disease control, irrigation, topping and sucker control were according to the recommended practices for commercial plantations (Anon, 1990).

At each of the 14 sites, 10 tobacco plants were randomly selected and tagged at the budding stage. Ripe leaves from the lower, middle and upper stalk positions that is lugs (X), cutters (C), leaf (B) and Tips (T) were harvested at around 10-15 days interval. In some cases, the tips were not available either because of drought or marked disease conditions. The leaves from all plants were bulked and taken to the laboratory. The midrib and leaf lamina were separated, cut into pieces, mixed thoroughly and a sample of about 500 g was oven-dried at 72°C.
Rainwater was collected in 3 separate containers laid randomly around some selected tobacco fields. Samples of water were collected after important rainfall events. Samples of irrigation water, where used and available, were taken for analysis.

Apart from pH, N, P and K analysis, soil samples were principally analysed for chloride so as to have an indication of the chloride level in the soil and also to determine its uptake and mobilization in the tobacco leaf. Leaf lamina and midrib samples were analysed for chloride and nicotine content while for both rain and irrigation water, only chloride content was determined. The chloride content was determined by titration using the silver nitrate method (Jackson, 1958). All analysis were carried out by the Agricultural Chemistry Division of the Ministry of Agriculture, Food Technology and Natural Resources.

RESULTS AND DISCUSSION

Leaf chloride level

The chloride level in the lamina ranged from a mean of 1.47% to as high as 4.35%(SE ± 0.23) while in the midrib, it varied from a mean of 3.11% to 8.9% (SE ± 0.36) (Table 2). This is therefore considered to be high in tobacco leaf manufacture. In general, the chloride content in the midrib was 2.5 times higher than in the lamina (Figure 2) and this result is in conformity with that found by Elliot (1967). The chloride level also varied according to the leaf position on the plant, being higher in the lower primings and gradually diminishing with successive primings except for a slight increase in the tips (Figure 2). This may be attributed to the state of ripeness of the leaves in the field and to the higher total dry matter content of the middle and upper leaves (Wolf, 1947).

There was also variation in the chloride content depending on the region where tobacco was grown. An attempt was made to classify the tobacco growing regions based on the leaf chloride level (Table 1). La Lucie, Clemencia and Beau Champ can be classified as those regions where tobacco can be cultivated with minimal chloride level (< 2%). On the other hand, Providence and Medine Camp de Masque are regions where tobacco production should be prevented since the chloride level in the tobacco leaf has reached unacceptable level (> 3%).

Nicotine content

Nicotine is the most important alkaloid in commercially grown tobacco (Ramahotar, 1990). The nicotine content did not differ significantly among the different localities (Table 2). Conversely to the chloride level, the nicotine content was higher in the lamina than the midrib. In both plant parts, the nicotine content increased from bottom to top of the plant (Figure 3). The mean nicotine content of the
Assessment of the chloride status in the tobacco leaf and some potential sources for the high chloride level. Y. Cadersa and A. Atawoo

Leaf averaged over growing regions was \((2.1 \pm 0.22)\) which is at par with those of Zimbabwe, India and Brazil (Chari, 1995).

Table 1 Classification of tobacco growing regions based on leaf chloride level.

<table>
<thead>
<tr>
<th>Class</th>
<th>% Leaf chloride level</th>
<th>Tobacco growing region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 2</td>
<td>La Lucie, Clementia and Beau Champ</td>
</tr>
<tr>
<td>Medium</td>
<td>2 –3</td>
<td>Pointe Lascars, Rivière du Rempart, Île D’ambre, L’Unité, Haute Rive, Richelieu, Grande Retraite, Palmar, Trou d’Eau Douce</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 3</td>
<td>Providence, Medine Camp de Masque</td>
</tr>
</tbody>
</table>

Figure 3 Relationship between plant position and nicotine content % in leaf lamina and mid rib

Rain and irrigation water

The mean chloride level in irrigation water was 0.57% at Beau Champ and Palmar and 0.14% at L’Unité while for rainwater collected at Providence, Medine, L’Unite, Flacq, Pointe Lascars and Clemencia, a mean chloride level of 0.28% was recorded. Both the irrigation and rain water had a chloride content above that recommended by Chari (1995) which is less than 0.05%, for the production of low chloride tobacco leaves. Consequently, such high chloride level in the irrigation water may have contributed to an increase in the leaf chloride as demonstrated by Murthy (1964).

Soil type and chloride level

Among the 14 sites under study, 6 belong to the Low Humic Latosol group, 5 to the Latosolic Reddish Prairie, 2 to the Lithosols and 1 to the Latosolic Brown Forest (Table 3). The mean chloride level in the soil ranged between 21 ppm to 71.5 ppm. Chari (1995) recommends growing tobacco on soil with less than 100 ppm chloride to produce leaves of low chloride content which is therefore in accordance to our findings (Table 3).
Table 2  Mean chloride and nicotine levels in leaf lamina and midrib in the major tobacco growing regions. (Mean of Lugs, cutters, leaf and tips)

<table>
<thead>
<tr>
<th>Major tobacco growing regions</th>
<th>Chloride level</th>
<th>Nicotine level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaf Lamina</td>
<td>Midrib</td>
</tr>
<tr>
<td></td>
<td>Mean ± SE</td>
<td>Mean ± SE</td>
</tr>
<tr>
<td>La Lucie Roy</td>
<td>1.52 ± 0.22</td>
<td>4.09 ± 0.34</td>
</tr>
<tr>
<td>Clementia</td>
<td>1.47± 0.35</td>
<td>3.90 ± 0.29</td>
</tr>
<tr>
<td>Pointe Lascars</td>
<td>1.89 ± 0.29</td>
<td>4.52 ± 0.47</td>
</tr>
<tr>
<td>Rivièredu Rempart</td>
<td>1.96 ± 0.13</td>
<td>4.48 ± 0.32</td>
</tr>
<tr>
<td>Île d’Ambre</td>
<td>1.70 ± 0.06</td>
<td>5.32 ± 0.29</td>
</tr>
<tr>
<td>Providence</td>
<td>4.35 ± 0.33</td>
<td>8.60 ± 0.58</td>
</tr>
<tr>
<td>Médine Camp de Masque</td>
<td>2.87 ± 0.62</td>
<td>8.90 ± 0.69</td>
</tr>
<tr>
<td>L’Unité</td>
<td>1.88 ± 0.30</td>
<td>5.82 ± 0.46</td>
</tr>
<tr>
<td>Haute Rive</td>
<td>2.33 ± 0.53</td>
<td>2.83 ± 0.59</td>
</tr>
<tr>
<td>Richelieu</td>
<td>2.23 ± 0.42</td>
<td>6.01 ± 0.47</td>
</tr>
<tr>
<td>Grande Retraite</td>
<td>1.63 ± 0.26</td>
<td>4.01 ± 0.30</td>
</tr>
<tr>
<td>Beau Champ</td>
<td>1.47 ± 0.40</td>
<td>3.11 ± 0.62</td>
</tr>
<tr>
<td>Palmar</td>
<td>1.90 ± 0.30</td>
<td>4.26 ± 0.60</td>
</tr>
<tr>
<td>Trou d’Eau Douce</td>
<td>2.04 ± 0.39</td>
<td>4.07 ± 0.67</td>
</tr>
<tr>
<td>SE ±</td>
<td>0.23</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Table 3  Soil pH and chloride level in relation to distance from the sea for the major tobacco growing regions

<table>
<thead>
<tr>
<th>Major tobacco growing areas</th>
<th>Soil Type</th>
<th>Distance from the sea km</th>
<th>Soil chloride ppm</th>
<th>Soil pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Top Soil 0 – 25 cm</td>
<td>Sub Soil 25 – 40 cm</td>
<td>Mean Top Subl Mean</td>
</tr>
<tr>
<td>Rivière du Rempart</td>
<td>LRP*</td>
<td>0.4</td>
<td>60</td>
<td>74</td>
</tr>
<tr>
<td>Pointe Lascars</td>
<td></td>
<td>0.6</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Beau Champ</td>
<td></td>
<td>1.7</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>La Lucie Roy</td>
<td></td>
<td>5.0</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>Clementia</td>
<td></td>
<td>6.5</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Ile d’Ambre</td>
<td>LHL**</td>
<td>6.5</td>
<td>57</td>
<td>86</td>
</tr>
<tr>
<td>Haute Rive</td>
<td></td>
<td>0.2</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>Richelieu</td>
<td></td>
<td>0.5</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Grande Retraite</td>
<td></td>
<td>3.0</td>
<td>57</td>
<td>29</td>
</tr>
<tr>
<td>L’Unité</td>
<td></td>
<td>11.6</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Medine Camp de Masque</td>
<td>Lithosols</td>
<td>13.5</td>
<td>41</td>
<td>64</td>
</tr>
<tr>
<td>Trou d’eau Douce</td>
<td></td>
<td>0.5</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Palmar</td>
<td></td>
<td>1.5</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Providence</td>
<td>LBF***</td>
<td>15.0</td>
<td>18</td>
<td>36</td>
</tr>
</tbody>
</table>

LRP*: Latosolic Reddish Prairie, LHL**: Low Humic Latosol, LBF***: Latosolic Brown Forest,

It is observed that the Latosolic Reddish Prairie (LRP) soil group, in particular Pointe Lascars and Rivière du Rempart closest to the sea gave a higher chloride level than those furthest away. This may be attributed to salt drifts during windy conditions along the coast. The Lithosol group (Palmar and Trou d’Eau douce) although close to the sea had lower chloride level indicative of the fact that distance from the seas may not be accountable for the high leaf chloride.

The LRP group did not differ greatly in its chloride content, which ranged between 24 to 72 ppm. The LBF group on the other hand has lower chloride content probably because of the climate characterized...
Assessment of the chloride status in the tobacco leaf and some potential sources for the high chloride level. Y. Cadersa and A. Atawoo

by high rainfall. In general, subsoil had a slightly higher chloride level than topsoil and the pH of the soil varied from highly acidic (4.5) to slightly acidic (6.4).

Factors influencing leaf chloride

No relationships were found between leaf chloride level (midrib or leaf lamina) and soil chloride level (Figure 4). Consequently, it appeared that other factors must be influencing chloride uptake and its mobilization into the leaf. This is in line with the findings of Murthy (1964) who concluded that plant chloride level seemed much more closely related to the chloride level of irrigation water than it was to the soil.

Similarly, a non-significant relationship was obtained between soil pH and both lamina and midrib chloride content (Figure 5). This result is in accordance with that of Akehurst (1981) who found that the chloride content of tobacco leaves was inversely related to soil pH.

Figure 4 Relationship between mean soil chloride ppm and mean % chloride level in leaf lamina and midrib

Figure 5 Relationship between mean soil pH and mean % chloride level in leaf lamina and midrib
CONCLUSION

This study demonstrates that tobacco produced in Mauritius contain chloride level above 1.5% which is therefore considered to be high in tobacco manufacture. Among the areas surveyed, three sites were identified where tobacco leaf could be produced with the minimal chloride level (1.0- 2.0%). Furthermore, when selecting sites for tobacco production, the previous crop history as well as other managerial practices such as source of irrigation water should be known since these are potential sources of the high chloride level. More importantly, the inclusion of the midrib in the leaf manufacture could also be revisited to produce tobacco with lower chloride level.

ACKNOWLEDGEMENTS

Thanks are expressed to the Tobacco Board, the British American Tobacco, tobacco planters and the Chemistry Division of the Ministry of Agriculture for their help in conducting this study. We are grateful to the Director, Mr P. Hanoomanjee and Mr. R. Ramnauth for having reviewed this paper.

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CHEMOSYSTEMATICS: A NEW SOURCE OF EVIDENCE FOR THE CLASSIFICATION OF THE ENDEMIC FLORA OF MAURITIUS

NR Lai Fang, T Bahorun and G Khittoo

Faculty of Science, University of Mauritius

ABSTRACT

Chemosystematics can be viewed as a hybrid science that complements available morphological data to improve plant systematics. Polyphenolics are among the chemical markers most extensively used in botanical chemosystematic studies. Preliminary analysis of flavonoid chromatographic migration profiles of four Mauritian endemic species of Eugenia have shown that E pollicina, E fasciculata, and E orbiculata are more closely related to each other as compared to E elliptica. Flavonoid profiles were also efficiently used for the identification of a Trochetia species, which due to the unavailability of reproductive organs, was erroneously suspected to be the probably extinct T parviflora.

Keywords: Chemosystematics, Phenolics, flavonoids, Eugenia, Syzygium, Trochetia.

INTRODUCTION

With the development of natural product chemistry, scientists have shown that phytochemical constituents can be used to characterize, describe, and classify species into taxa. Correlations between traditional morphological and chemical classifications can be traced as early as 1699 (Fairbrothers 1968). However, a genuine interest in the understanding of possible relationships between plant constituents and systematics is more recent. Interest in this aspect of systematics has increased with the development of rapid and precise analytical techniques, and there is a consensus that data from as many sources as possible should be employed in plant classification (Stace 1980 cited in Datta 1988).

Evidence from chemical constituents has already led to the reconsideration of many plant taxa. For example a number of taxonomically difficult families have been successfully grouped on the basis of their secondary metabolite profiles. The Bonnetiaceae, which consists of the two genera Bonnetia and Archytaeae is in fact better associated with the Guttiferae than with the Theaeceae as the presence of xanthones would suggest (Waterman 1998). Placement of the Bretschneideraceae in the Capparales rather than in the Sapindales is supported by the occurrence of glucosinolates (Waterman 1998). At lower taxonomic levels, several metabolites have proved useful in establishing taxonomic relationships. The distribution of indole, and carbazole alkaloids, 8-prenylated coumarins and monoterpenes or sesquiterpenes dominated volatile oils have been combined to confirm the division of the genus Murraya (Rutaceae) into two taxa.

In fact, three broad categories of plant chemical constituents are normally used for systematic purposes. These include the primary metabolites, the secondary metabolites, that is those not involved in basic metabolism of the cell, and the semantides, which are information-carrying molecules such as DNA (primary), RNA (secondary), and proteins (tertiary). Sometimes, another categorization of the systematic markers can also be defined, where the primary and secondary metabolites are referred to as micromolecules and the semantides along with the larger polysaccharides as macromolecules. This latter classification has lead to the division of chemical systematics itself into two entities. Thus chemosystematics, in the widest sense of the word, involves both micromolecules and macromolecules as systematic markers. However, very often, the term is restricted to micromolecular systematics, involving primary and more often the secondary metabolites.

From a taxonomic point of view, phenolics have proved to be the most popular type of secondary metabolite (Smith, 1976), and the number of chemosystematic studies based on these markers have extensively been reported. The main reason for their popularity is their quick and simple extraction from plant material. Also they are relatively easy to separate by chromatography, and are readily identified by location reagents (Smith 1976).

Among the different phenolic groups, flavonoids have been the most successfully used chemosystematic markers. Numerous examples where chemosystematic investigations have been
based on flavonoids have been reported. These include the flavonoid survey of 5 genera of the Calyceraceae (Bohm et al. 1995), the study of the flavonoids of Bignoniaceae from the “cerrado” and their taxonomic significance (Blatt et al. 1998), the work carried out on Podalyriaceae and Lipariaceae tribes based on seed flavonoids (De Nysschen et al. 1998), and the study of the distribution and chemotaxonomic significance of flavonoids in Aloe (Viljoen et al. 1998) are some examples.

Harborne (1973) qualified flavonoids as being probably the most useful class of secondary plant constituents from a systematic point of view. Over the last 30 years, flavonoids have proved to be determinant at all levels of plant taxonomy (Van Sumere et al. 1993). On this basis, whole plant families have been included in or excluded from specific orders. It has also been possible to assign particular flavonoid patterns at the family and species level (Harborne 1973). Flavonoids have even proved to be significant in the identification of natural plant hybrids, such as Baptisia (Harborne, 1973) and the recognition of plant cultivars such as Azalea and hops (Van Sumere et al. 1985, 1988 cited in Van Sumere 1993).

Flavonoids show enormous structural variation. They can be divided into a dozen of subclasses, each of them varying in the degree of hydroxylation, methylation and glycosylation. Consequently flavonoids provide at least as many scorable characters as any other group of secondary substances. They also have the advantage to be more widely distributed than most other secondary substances. Flavonoids occur universally in angiosperms, gymnosperms and pteridophytes and therefore their use as chemosystematic markers is not restricted. In addition flavonoids seem to be amongst the most stable chemical characters in plants. Qualitative variation at the species level is very limited. Moreover, when it comes to ease and speed of identification, flavonoids are again highly rated (Harborne 1967).

Mauritius is known to possess a very diverse flora composed of over 700 species of indigenous plants of which about 300 (about 60%) are endemic (Guého 1988). With such a diverse flora, coupled with a high proportion of endemism, the island’s vegetation offers much scope for taxonomic and phylogenetic studies. However the taxonomy of the endemic Mauritian flora has so far been exclusively based on traditional morphological features. Though traditional morphological taxonomy has helped in the understanding of the Mauritian flora, much work remains to be done. For instance, many taxa still remain problematic with cases of heterophylly, heteroblasty, hybridization, and with natural morphological similarities. Moreover, most of the time, reproductive parts are unavailable from these plants, making traditional morphological methods unreliable. Although a number of investigations of the phytochemistry of the Mauritian endemic plants exist, they relate more to traditional aspects of the plant and the biological activities of its extract, rather than to the systematics of these plants. Among the very few chemosystematic survey carried out on Mauritian endemic plants, we should note Bate-Smith’s study, in 1977, of flavonoids of the Cunoniaceae where 3 species of Weinmannia; W. laevis Lamk, W. macrostachys DC., and W. tinctoria Sm., were considered. Ellagic acid, kaempferol, quercetin, and cyanidin were identified from these samples (Stuessy 1998).

The need to have more information about the systematics of the vegetation of the island is even more important considering the fact that a high proportion of the Mauritian indigenous plants has already been categorised as threatened or endangered and are liable to disappear before any study is initiated on them. In such cases, taxonomy based on both chemosystematic, and traditional morphological data where available, will definitely help for a better conservation management of these threatened species. Furthermore, chemosystematic surveys on the Mauritian endemic flora can prove to be informative in the screening of natural biologically active products more particularly the polyphenolics to which a wide range of properties including antiviral (Jurd et al. 1971, Zhou et al. 1992), antibacterial (Didry et al. 1982), antifungal (Ravn et al. 1984, Weidenborner et al. 1993), anti-inflammatory (Bidet et al. 1987), anticarcinogenic (Hertog et al. 1992, Das et al. 1994, Kasai et al. 2000) and antioxidant (Yuting et al. 1990, Bahorun et al. 1994, 1996, Liu et al. 2000, Martinez et al. 2000) activities have already been attributed.

In this paper, we report the preliminary chemosystematic investigation on four endemic Eugenia species (E. elliptica, E. fasciculata, E. pollicina, E. orbiculata) and the identification of an individual of the genus Trochetia to the species level based on chemical constituents.
MATERIALS AND METHODS

Plant material

Leaf samples were collected from E. elliptica, E. pollicina, E. fasciculata and E. orbiculata. For the identification of the Trochetia species suspected to be T. parviflora, leaves were collected from species of T. blackburniana, T. boutoniana, T. triflora, T. uniflora, and the unidentified Trochetia species. A leaf of T. parviflora, was kindly provided by the Mauritius Herbarium.

Sample preparation

In the investigation of the chromatographic profiles of the 4 Eugenia species, fixed masses of leaves from each species were blended in acetone/water (70/30 v/v) and left overnight at 4 °C before being filtered. The residues were finally extracted overnight again at 4°C with 100% MeOH. The filtrates were concentrated under reduced pressure to eliminate organic solvents. The remaining aqueous extracts were then washed with dichloromethane to remove chlorophylls before freeze-drying. Aliquots of freeze-dried total extracts of each species were dissolved in 100 ml of distilled water and the solution extracted extensively with ethyl acetate. The ethyl acetate phases were then dehydrated with anhydrous sodium sulphate (Na 2SO4) before being low-pressure evaporated to dryness and taken up in absolute methanol to yield a 1:2.5 (plant fresh weight/volume) ratio.

For the analysis of Trochetia species, 5g of leaves of Trochetia boutoniana, Trochetia blackburniana, Trochetia triflora, Trochetia uniflora and the unidentified Trochetia species, and 0.0421g of leaf tissue of T. parviflora (herbarium specimen) were grounded in liquid nitrogen and left to macerate for 24 h at +4 °C in acetone/water (70/30 v/v), and finally in absolute methanol. The collected filtrates were concentrated under reduced pressure to eliminate organic solvents. The remaining aqueous phases were washed with dichloromethane to remove chlorophylls before being freeze-dried (For T. parviflora, the aqueous extract was evaporated to dryness). The residues obtained were then dissolved or taken up in 15% ethanol to obtain a 1/5 (plant fresh weight/ volume) ratio.

Chromatography analysis

Leaf extracts of the 4 Eugenia species were examined by one-dimensional thin layer chromatography on silica gel coated plates (K6F, Whatmann). Flavonoids were separated in Ethyl acetate/Formic acid/Glacial acetic acid/Water (100/11/11/26) and visualized by 1% 2-aminoethyldiphenyl borinate solution in methanol, followed by 5% polyethylene glycol 4000 in absolute ethanol at 365 nm (Wagner and Bladt 1996).

Leaf extracts of the Trochetia species, were analysed by High Performance Liquid Chromatography. A HP 1100 series liquid chromatography system comprising vacuum degasser, quaternary pump, autosampler, thermostatted column compartment and diode array detector was used. Analysis was carried out at 25 °C after filtration of total extracts on millipore (0,22nm) and injection ( 30 µl) on a Lichrosorb RP 18 column (0,5 µm; 4.6 mm id x 150 mm; 25°C) by an acidified acetonitrile-water gradient. Elution (flow rate : 0.7 ml/ min) was performed in the following order: 0-30 minutes, 0-15 % B in A; 30-50 minutes, 15% B in A; 50-60 minutes, 15-25 % B in A; 60-90 minutes, 15-100 % B in A; 90-100 minutes, 100-0 % B in A [Solvent A: acetonitrile/ water, 1/9 v/v, pH 2.6; Solvent B: acetonitrile/ water, 1/1 v/v, pH 2.6]. Absorption wavelength was selected at 360 nm for detection of flavonoids.

RESULTS AND DISCUSSION

Table 1 gives the Rf values and the tentative identities of some of the flavonoids detected in E. elliptica, E. pollicina, E. fasciculata, and E. orbiculata.

Our results show that a more or less similar flavonoid pattern occurs in the four Eugenia species. Four out of five flavonoid compounds were commonly detected, in the four species thereby supporting their classification within the same genus Eugenia. However, among these four species, E. elliptica appears as the most distant member as the flavonoid compound F4 (Rf~0.7) which is prominent in E. fasciculata, E. pollicina, and E. orbiculata, was not detected in E. elliptica. Furthermore, the chromatographic profile of E. elliptica seems to be less complex in terms of flavonoid composition compared to the 3 other Eugenia species. This difference seems to be in accordance with
morphological data. Leaves of *E. elliptica*, for instance, are larger than those of *E. pollicina*, *E. fasciculata*, and *E. orbiculata* which are themselves almost similar in size. Also leaves of *E. elliptica* are acute at the apex, while those of *E. pollicina*, *E. fasciculata*, and *E. orbiculata* have obtuse apices. More often, leaves of *E. elliptica* have more than 10 pairs of lateral veins, whereas those of the 3 other species usually have less (Bosser 1987).

**Table 1** Distribution of flavonoids detected by Thin Layer Chromatography (Ethyl acetate / Glacial acetic acid / Formic acid / Water, 100 : 11 : 11 : 26) of Ethyl Acetate extracts of *E. elliptica*, *E. pollicina*, *E. fasciculata*, and *E. orbiculata*.

<table>
<thead>
<tr>
<th>Species</th>
<th>F1 (~0.95)</th>
<th>F2 (~0.9)</th>
<th>F3 (~0.8)</th>
<th>F4 (~0.7)</th>
<th>F5 (~0.62-0.66)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Isoquercitrin</td>
<td>Hyperoside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tentative Identity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. elliptica</em></td>
<td>++</td>
<td>+</td>
<td>(+)</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><em>E. pollicina</em></td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td><em>E. fasciculata</em></td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td><em>E. orbiculata</em></td>
<td>++</td>
<td>++</td>
<td>(+)</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Flavonoid profiles have also proved to be efficient analytical tools for proper identification at the species level. This is clearly exemplified within the genus *Trochetia* where an unidentified *Trochetia* species from “Crownland L’étard” near “Le Poucé”, was suspected to be the probably extinct *T. parviflora*. This was based mainly on the morphology of leaves as flowers were unavailable, and on the site of occurrence of the plant. Literature data (Bosser 1987) gives clear indication of the possible occurrence of *T. parviflora* in the region of “Le Poucé”. The flavonoid profile of the leaf extract of the unidentified *Trochetia* species, obtained by chromatography was compared with those of the other *Trochetia* species. Comparison was also made with the probably extinct *T. parviflora*. HPLC flavonoid patterns of the unidentified species and *T. uniflora* were found to be remarkably similar. The overlay of their chromatograms (Figure 1) shows the striking similarity in their profiles. These results clearly illustrate that the unidentified *Trochetia* species is more likely to be *T. uniflora* itself and not the probably “extinct” *T. parviflora* as leaf morphology led to believe previously. In fact the low flavonoid pattern similarity between *T. parviflora* and the unidentified *Trochetia* species tends to strongly suggest that these two species are different (Figure 2). Furthermore, the flavonoid profile of the unidentified *Trochetia* species was found to be considerably different from those of the other three species of *Trochetia*, namely *T. blackburniana*, *T. boutoniana*, *T. triflora*. The results consequently points out that the unidentified *Trochetia* from “Crownland L’étard” is not likely to be one of these three species.

**Figure 1** Overlay diagram of HPLC flavonoid profiles (total leaf extracts) of *T. uniflora* and *Trochetia* species from crownland l’étard. Chromatograms were recorded at 360 nm.
CONCLUSION

Flavonoid patterns of leaf extracts based on TLC have shown readily that *E. elliptica* is quite different from the related species of *E. orbiculata*, *E. pollicina*, and *E. fasciculata* which share similar chromatographic profiles. This seems to strongly correlate with morphological features. Given the marked similarity of the flavonoid profiles of the unidentified *Trochetia* species and that of the *T.uniflora* it is reasonable to believe that they are the same species. The difference in HPLC flavonoid patterns between the unidentified *Trochetia* species and the *T. parviflora* clearly indicate that they were different species. Traditional morphological taxonomy alone can be limited in some cases and for this particular reason other sources of information such as chemosystematic data can definitely improve the systematics of the Mauritian endemic flora. Similar to the *Trochetia* case depicted in this paper there exist numerous reports where polyphenolics have been used for the precise classification within genera where morphological and anatomical classifications were complicated. Among the well known examples are *Attalea* (Williams et al. 1983a), *Lupinus* (Williams et al. 1983b), *Vicia* (Webb and Harborne 1991), *Ostericum* and *Angelica* (Harborne et al. 1986), *Hieracium* (Petrovic et al. 1999) and *Betula* L. species (Keinänen et al. 1999). While chemosystematics cannot replace traditional systematics based on morphology and anatomy, it will certainly provide a major source of new characters and information to complement these methods for reliable taxonomy. This will lead to a more comprehensive understanding of the systematics, evolution, ecology and the elaboration of better conservation strategies of the endemic flora of Mauritius.

ACKNOWLEDGEMENTS

The authors acknowledge the Forestry Service, Ministry of Agriculture, Food Technology and Natural Resources for providing leaf samples and the Mauritius Herbarium for supplying the *Trochetia parviflora* herbarium leaf specimen. The work was supported by the University of Mauritius Research Grant Scheme and the Tertiary Education Commission.
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ORGANIC AGRICULTURE: A MYTH OR REALITY IN THE MAURITIAN CONTEXT?

S Facknath and B Lalljee
University of Mauritius

ABSTRACT

Mauritian agriculture is at a crossroads, and recent events have demonstrated very clearly that the country is ready to embark on new ventures. Apart from the well-known hazards of excessive agrochemical use, the decline in the sugar industry and the effects of globalisation on the doorstep, Mauritius is ready to explore other export-oriented agricultural products in niche markets. One such alternative can be organic produce, for the domestic and tourist sectors as well as for export. Organic agriculture is the “cultivation that not only excludes the use of synthetic agents or agro-chemicals, but which maintains or even improves the fertility, organic quality and sustainability of the soil”. Lists of permitted fertilisers and soil amendments, pest and disease control agents, substances used during processing of foodstuffs, etc. have been prepared by international organizations and are available to farmers, scientists and policy makers. Mauritius already possesses a number of important characteristics favourable for organic agriculture, while others need improvement.

Key words: ecological agriculture, sustainable agriculture, environmentally-friendly agriculture, non-synthetic and natural pesticides and fertilisers

INTRODUCTION

Over the years, successful agricultural production has come to depend heavily on fertilisers and pesticides. The trend in developed countries towards promoting a healthy lifestyle has made people take a closer look at the food they eat, and the steps leading to its production and processing. The realization that several of the practices of conventional agricultural production are harmful, both to human health and to the environment, was not long in coming, and led to the emergence of alternative forms of agriculture, such as Sustainable Agriculture, Low External Input Sustainable Agriculture (LEISA) and Organic Agriculture. Organic farming can be said to be an extreme type of alternative agriculture wherein the use of synthetic fertilisers and pesticides is completely replaced by natural and/or non-synthetic forms of crop fertilisation and protection.

The concept of organic agriculture is that it is a system of elements oriented towards sustainability and based on the ecological laws governing the relations and interactions between plants and their natural environment. Organic agriculture has been defined, in practical terms as, “the cultivation that not only excludes the use of synthetic agents or agro-chemicals, but which maintains or even improves the fertility, organic quality and sustainability of the soil”.

In the case of a processed product, only non-synthetic and natural additives and non-agricultural ingredients are permitted. In order to ensure compliance with set criteria, all the stages, from the field through processing and trade to market, are regulated and monitored.

Historical background

The precursors of modern-day organic farming are to be found in the US in the late nineteenth century and the early 1920s and 1930s. Specialist food products, labelled as “green foods”, “health foods”, “whole foods”, “ecological foods”, “environmentally-friendly foods”, “pesticide-free foods”, etc. made their appearance in special health food shops, and the fashion for buckwheat, wheat germ, yeast, unpolished whole grain and whole-milk yoghurt was started. However, in spite of their evocative names, none of these products could be considered as truly ‘organic’.
At a later stage in history, the “back-to-the-land” movement of the 1960s and 1970s precluded any use of synthetic agro-chemicals in foods. However, this was more of a philosophy of life, and an ideology, rather than a commercial idea.

Still later, the recession of the 1980s forced some farmers into turning ‘organic’ mainly to avoid the high-cost input of conventional agriculture (Buley et al, 1997).

Increasing local and international trade in organic produce in the late sixties, and the increasing public demand for a high quality, consistent and standard product highlighted the need for set criteria and guidelines for production and processing of organic foods. 1972 saw the creation and establishment of the International Federation of Organic Agricultural Movements (IFOAM), which, for the first time, laid down clear and consistent definitions for ‘organic foods’, ‘organic crop production’, etc. Although having started in the US, it was in Europe that organic agriculture really took off. Standards, criteria and legislation for production and marketing of organic produce were established in Germany in 1990, and in the rest of Europe, in 1993. By 1995, 30 states in the US had their own laws regulating production, processing and marketing of organic foods, and in 1997, National Standards were set by the USDA (Buley et al, 1997).

While the EU and US standards and criteria are slightly different, the basic requirements for any produce to be considered as ‘organic’ is more or less the same (Anon, 1999; Buley et al, 1997; FIBL, 1999), namely:

An agricultural product which

i. Has been produced and handled without the use of synthetic chemicals;
ii. Has not been produced on land to which any prohibited substances, including synthetic chemicals, have been applied during the 3 years immediately preceding the harvest of the said products; and
iii. Has been produced and handled in compliance with an organic plan agreed to by the producer and handler of such product and the certifying agent.

The early organic market in Europe suffered from high prices of the organic produce, limited range of organic foods, small numbers of retail outlets selling organic foods, doubts about the origin of the foods, and inferior quality of the produce. However, with the establishment of appropriate legislation, strict inspection and monitoring, availability of an increasingly wider range of organic foods, increasing numbers of shops and supermarkets stocking organic foods and ever-improving quality, the market for organic foods has been steadily increasing over the years in developed countries.

**Principles and components of organic farming**

The principles and components of organic crop agriculture are as follows:

1. The land to be farmed organically must undergo a specified conversion period to ensure that any residual synthetic fertilizer or pesticide in the soil is completely degraded (normally 2-3 years, but may be reduced or extended by the inspection body according to previous land use);
2. The area certified as being organic must have well-defined boundaries with buffer zones separating this area from land that is not organic;
3. Must have appropriate physical facilities, machinery and management practices to prevent mixing of organic and non-organic products;
4. Seeds, and other planting material, must be from an organic source and must not be genetically modified / engineered in any way, except through natural breeding practices;
5. Only natural and / or non-synthetic, organic fertilizers and soil conditioners must be used (Table 1);
6. Fertility and biological activity of the soil must be maintained or increased by adding organic material, composted or not, and with or without the use of micro-organisms and plant-based preparations for compost activation;
7. Fertility and biological activity of the soil must be maintained or increased by using green manures, natural sources of nitrogen and deep-rooted plants in an appropriate multiannual rotation programme;
8. Pests, diseases and weeds must be controlled by using physical, mechanical, cultural, biological and biology-based methods, and through the use of resistant varieties/species;
9. Natural enemies of pests must be protected and/or augmented through provisions favourable to them;
10. Only natural and/or non-synthetic pest and disease control measures must be used (Table 2);
11. Only permitted additives, flavourings, etc. must be used in processed foods (Table 3);
12. Only permitted substances must be used as processing aids (Table 4);
13. The finished organic products must be kept separate from other products and be clearly labelled as per established norms (e.g. as per the US Federal Laws, organic bread can only be so labelled if it contains at least 95% organic ingredients);
14. Produce must be certified by an independent third-party certifier;
15. All records must be kept in accordance with regulations, and made available to the inspector at any time.

Certification involves inspection of the product at all stages of production, processing, packaging and marketing. Record keeping is an important aspect of certification, and accurate and detailed records must necessarily be kept of every fertilizer, pest control measure applied, as well as any additive/ingredient used for processing (FIBL, 1999).

Organic agriculture is not limited to organic crops alone, but also includes organic animal production. Below are listed some of the important regulations for organic animal farming.

1. Livestock must be fed with organic feed;
2. No plastic pellets must be used as roughage;
3. There must be no manure refeeding;
4. No urea-containing feed must be given to the animals;
5. No growth promoters or hormones or sub therapeutic doses of antibiotics or synthetic trace elements must be given;
6. No synthetic internal pesticides/parasiticides must be administered;
7. No medication, except for vaccines must be given, in the absence of illness;
8. Water must be of drinking quality standard;
9. Salt provided must be clean and pure.

Table 1 Permitted Fertilisers and Soil-conditioners

1. Composted or partially composted farmyard manure and poultry manure, horse manure, slurry or urine, piggery wastes
2. Straw
3. Peat (only for horticulture)
4. Composts from spent mushroom
5. Vermicompost and dejects of insects
6. Composts from organic household refuse (only up to 31.3.2002)
7. Composts from vegetable/plant matter
8. Guano
9. Products and by-products of plant origin (oilseed cake meal, cocoa husks, malt culms, coconut fibres and dust, etc)
10. Processed animal products from slaughterhouses and fish industries (blood meal, hoof meal, horn meal, bone meal, animal charcoal, fish meal, meat meal, feather & hair meal, wool, fur, dairy products)
11. Organic by-products of foodstuffs and textile industries
12. Seaweeds and seaweed products (obtained by specific methods)
13. Sawdust, bark and wood wastes, Wood ash (wood not treated chemically after felling)
14. Natural phosphate rock
15. Calcinated aluminium phosphate rock, Rock potash, Sulphate of potash
16. Crude potassium salt (kainite, sylvinites, etc)
17. Sodium tetra borate, Sodium molybdate, Sodium chloride
18. Basic slag
19. Industrial lime from sugar production (only up to 31.3.2002), vinasse, scum, molasses
20. Limestone, Chalk, Marc
21. Magnesium rock, Calcareous magnesium rock, Epsom salt (magnesium sulphate)
22. Gypsum (calcium sulphate), Calcium chloride
23. Manganese carbonate, Zinc carbonate, Iron carbonate
24. Trace elements (B, Cu, Fe, Mn, Mo, Zn)
25. Elemental Sulphur
26. Stone meal
27. Clays (vermiculite, bentonite, perlite)

**Table 2** Permitted Products for Plant Protection
*Source: FiBL, 1997a, 1997b, 1999, 2000a, Buley et al., 1997*

1. Pyrethrums extracted from *Chrysanthemum cinerariaefolium*
2. Azadirachtin extracted from *Azadirachta indica*
3. Rotenone extracted from *Derris* spp., *Lonchocarpus* spp., and *Tephrosia* spp.
4. Quassia extracted from *Quassia amara*
5. Preparations from *Ryania speciosa*
6. Aqueous extracts from *Nicotiana tabaccum* (only for specific pests and up to 31.3.2002)
7. Potassium permanganate
8. Propolis
9. Hydrolysed proteins
10. Diatomaceous earth
11. Stone meal
12. Quartz sand
13. Sulphur, lime sulphur (calcium polysulphide)
14. Bordeaux mixture
15. Burgundy mixture
16. Copper, copper hydroxide, copper oxysulphate, copper oxychloride, copper sulphate, cuprous oxide (up to 31.3.2002)
17. Sodium silicate
18. Sodium bicarbonate
19. Fatty acid potassium soap (soft soap)
20. Pheromone preparations
21. *Bacillus thuringiensis* preparations (not genetically modified)
22. Granulose virus preparations (not genetically modified)
23. Fungal preparations (not genetically modified)
24. Mineral oils (against specific pests, and up to 31.2.2002); Plant and animal oils
25. Paraffin oil
26. Diammonium phosphate (in traps and/or dispensers only, no contact with crop)
27. Metaldehyde (in traps and/or dispensers only, no contact with crop) (up to 31.3.2002)
28. Pyrethroids (only deltamethrin or lambda-cyhalothrin) (in traps only, against specific pests, such as fruit flies)

**Table 3** Permitted Ingredients of Non-Agricultural Origin
*Source: Anon, 1999, Buley et al., 1997*

1. Food additives (calcium carbonates, lactic acid, carbon dioxide, malic acid, ascorbic acid, tocopherol rich extract, lecithins, citric acids, calcium citrates, tartaric acids, sodium tartrate, potassium tartrate, monocalcium phosphate, alginic acid, sodium alginate, potassium alginate, agar, carrageenan, locust bean gum, guar gum, arabic gum, xanthan gum, karaga gum, pectin, sodium carbonates, potassium carbonates, ammonium carbonates, magnesium carbonates, calcium sulphate, sodium hydroxide, argon, nitrogen, oxygen)
2. Flavourings
3. Water of drinking quality
4. Salt (sodium chloride or potassium chloride)
5. Micro-organism preparations normally used in food processing (not genetically modified)
6. Micro-organism preparations normally used in food processing (genetically modified according to specified procedures)
Organic Agriculture: a myth or reality in the Mauritian context? S. Facknath and B. Lalljee

Table 4 Substances Permitted During Processing
Source: Anon, 1999, Buley et al., 1997

<table>
<thead>
<tr>
<th>No.</th>
<th>Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Water</td>
</tr>
<tr>
<td>2.</td>
<td>Calcium chloride, calcium carbonate, calcium hydroxide, calcium sulphate</td>
</tr>
<tr>
<td>3.</td>
<td>Magnesium chloride</td>
</tr>
<tr>
<td>4.</td>
<td>Potassium carbonate</td>
</tr>
<tr>
<td>5.</td>
<td>Sodium carbonate, Sodium hydroxide</td>
</tr>
<tr>
<td>6.</td>
<td>Carbon dioxide, Nitrogen, Sulphuric acid</td>
</tr>
<tr>
<td>7.</td>
<td>Ethanol, Tannic acid</td>
</tr>
<tr>
<td>8.</td>
<td>Egg white albumen, Casein, Gelatin, Isinglass, Beeswax</td>
</tr>
<tr>
<td>9.</td>
<td>Vegetable oils</td>
</tr>
<tr>
<td>10.</td>
<td>Silicon dioxide gel or colloidal solution</td>
</tr>
<tr>
<td>11.</td>
<td>Activated carbon, Talc, Bentonite, Kaolin, Diatomaceous earth, Perlite</td>
</tr>
<tr>
<td>12.</td>
<td>Micro-organism preparations and enzymes normally used as processing aids (not genetically modified)</td>
</tr>
<tr>
<td>13.</td>
<td>Micro-organism preparations and enzymes normally used as processing aids (genetically modified according to specified procedures)</td>
</tr>
</tbody>
</table>

Today, a large number of countries produce organic foods and other products, mainly for export to Europe and the US. Table 5 lists some organic foods/products exported to Europe from developing countries.

The range of organic foods is wide and is increasing further. Apart from food stuffs (vegetables, fresh fruits, dried fruits, cereals, grain, baby foods, processed foods such as soups, sauces, ketchup, juices, sausages, burgers, etc), there is a market for even non-food products made organically, e.g. cotton, silk, hemp used in various industries, cotton-seed oil, sesame oil used in the cosmetic industry, aromatic oils such as clove oil, citrus oil, lemon grass oil, ylang-ylang oil, etc. used in naturopathy. Landscaping, gardens, golf courses and skiing slopes are also created and maintained according to the principles of organic management.

Characteristics of organic agriculture

Yield

DOC-field trials (a formalized system of evaluation and comparison of Bio-Dynamic, Organic and Conventional agricultural practices) have shown that, in general, yields from organic fields can be 20% lower in the first few years of conversion. However with savings of 50% in fertiliser costs, significant reduction in pesticide costs, and a market price 40% higher than for conventional produce, organic farming can bring healthy profits (FiBL, 2000b). Yields tend to increase on a long-term basis.

Nutrient Balance in Soils

Generally, the balance of the major nutrients, N, P, K, is negative in organic soils. However, appropriate, site-specific measures can easily remedy the situation, e.g. N-deficiency can be compensated for by improved N-fixation, or addition of N-rich soil amendments. K-deficiency can be corrected by improved management practices (increased cover-cropping, preventing K-volatilisation from compost, addition of K-rich soil amendments, etc) (Jannasch et al, 2000).

Soil Health

Organic soils have higher levels of organic matter, no acidification, better soil structure and much less erosion. An FAO study (1997) states that 25-50,000 million tones of arable soil are lost annually by erosion, and 5-20% fertile, arable ground is destroyed every year due to modern-day agricultural practices. A comparison of organic and conventional farms over two decades in Switzerland has shown that organic soils were much more stable and showed significantly less erosion (Remund, 2000).
## Table 5 Organic Imports into Europe from Developing Countries

*Source: Buley et al., 1997*

<table>
<thead>
<tr>
<th>Name of Product</th>
<th>Nature of product</th>
<th>Country of Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Unprocessed</td>
<td>India</td>
</tr>
<tr>
<td>Beans</td>
<td>Soy, kidney, mungo, azuki, etc.</td>
<td>Nicaragua, Zimbabwe, Paraguay, Mexico, Brazil</td>
</tr>
<tr>
<td>Cashew nuts</td>
<td>Unprocessed / nut paste</td>
<td>Moldavia, China, S. Africa, Brazil, India, Sri Lanka, Mozambique</td>
</tr>
<tr>
<td>Peanuts</td>
<td></td>
<td>Mexico, Paraguay, Israel, China</td>
</tr>
<tr>
<td>Walnuts</td>
<td>Unprocessed / cracked</td>
<td>Turkey</td>
</tr>
<tr>
<td>Apricots and Dates</td>
<td>Unprocessed / processed</td>
<td>Turkey, Tunisia, Morocco, Israel</td>
</tr>
<tr>
<td>Mango</td>
<td></td>
<td>Togo, Burundi, Burkina Faso, Senegal, Costa Rica, Colombia</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>Dried</td>
<td>China</td>
</tr>
<tr>
<td>Papaya</td>
<td></td>
<td>Togo</td>
</tr>
<tr>
<td>Coconut</td>
<td>Chips. Dried / flakes/oil</td>
<td>Madagascar, Dominican Republic</td>
</tr>
<tr>
<td>Pumpkin seeds</td>
<td></td>
<td>China</td>
</tr>
<tr>
<td>Cardamom</td>
<td></td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>Chilli</td>
<td></td>
<td>Egypt</td>
</tr>
<tr>
<td>Cinnamon</td>
<td></td>
<td>Madagascar, Sri Lanka</td>
</tr>
<tr>
<td>Cloves</td>
<td></td>
<td>Madagascar, Sri Lanka, Tanzania, Brazil</td>
</tr>
<tr>
<td>Vanilla</td>
<td></td>
<td>Madagascar, Tonga, India</td>
</tr>
<tr>
<td>Peppers</td>
<td></td>
<td>Madagascar</td>
</tr>
<tr>
<td>Ginger</td>
<td></td>
<td>Tanzania, India, Togo, Papua New Guinea</td>
</tr>
<tr>
<td>Olives</td>
<td></td>
<td>Morocco</td>
</tr>
<tr>
<td>Black tea</td>
<td></td>
<td>India, Assam, Sri Lanka, Kenya, Tanzania</td>
</tr>
<tr>
<td>Green tea</td>
<td></td>
<td>China, Nepal, Japan</td>
</tr>
<tr>
<td>Coffee</td>
<td></td>
<td>India, Papua New Guinea, several S. American countries</td>
</tr>
<tr>
<td>Cacao</td>
<td></td>
<td>Brazil, Costa Rica, Panama</td>
</tr>
<tr>
<td>Rapadura (cane sugar)</td>
<td></td>
<td>Mauritius</td>
</tr>
<tr>
<td>Honey</td>
<td></td>
<td>Australia, Mexico</td>
</tr>
<tr>
<td>Ylang-Ylang oil</td>
<td></td>
<td>Madagascar</td>
</tr>
<tr>
<td>Vetiver oil</td>
<td></td>
<td>El Salvador</td>
</tr>
<tr>
<td>Basil &amp; Lemon grass oils</td>
<td></td>
<td>Egypt</td>
</tr>
<tr>
<td>Lemon grass oil</td>
<td></td>
<td>Tanzania</td>
</tr>
<tr>
<td>Cotton</td>
<td></td>
<td>Egypt, Turkey, Peru, Ecuador</td>
</tr>
<tr>
<td>Silk</td>
<td></td>
<td>India</td>
</tr>
<tr>
<td>Hemp</td>
<td></td>
<td>Hungary</td>
</tr>
<tr>
<td>Henna</td>
<td></td>
<td>Egypt</td>
</tr>
<tr>
<td>Aloe Vera</td>
<td></td>
<td>Honduras</td>
</tr>
<tr>
<td>Fresh vegetables (tomatoes, cucumbers, potatoes, carrots, corn, zucchini, garlic, onion, etc., etc.)</td>
<td>Israel</td>
<td></td>
</tr>
<tr>
<td>Fresh fruits (bananas, papayas, melons, grapes, avocados, oranges, lemons, dates, grapefruits, mango, etc., etc.)</td>
<td>Israel</td>
<td></td>
</tr>
</tbody>
</table>
Soil Biology

Organic soils had increased numbers of carabids, staphilinids, spiders, earthworms, etc., all of which play an important and positive role in soil health and fertility. The microbial biomass, microbial activities were also much higher, which meant that nutrients would be better recycled and quicker, and soil structure was improved.

Biodiversity

The biodiversity on the farms is better conserved and includes a larger number of plant and animal species. Hence the agro-ecosystem is more stable and more resistant to stress and disturbance.

Energetics

Organic farming uses much less fossil energy as compared to conventional practices in the form of fertilisers, pesticides, fuel, etc. and hence is more sound, in terms of the energy dynamics

Organic agriculture in Mauritius

Agriculture in Mauritius is presently being practiced at the expense of large amounts of fertilisers (in sugarcane and other crops), and pesticides (as herbicides in sugarcane fields and insecticides, fungicides in the vegetable and fruit sectors). With the decline in the sugar industry and the effects of globalisation on the doorstep, Mauritius needs to explore other export-oriented agricultural products in niche markets. One such alternative can be organic produce, for the domestic and tourist sectors as well as for export. Mauritius already possesses a number of important characteristics favourable for organic agriculture, while others need improvement.

Below are listed some important characteristics of Mauritian agriculture and society that favour organic agriculture:

1. A strong R & D system, with organizations like AREU, MOA, MOE, UOM and MSIRI.
2. Well-equipped labs at all these institutions, which can enable the required soil and food analyses.
3. An efficient extension service.
4. Good infrastructure, an extensive network of roads, which cover the whole island.
5. Easy accessibility to farmers, and of farmers to scientific, technical and marketing services.
6. A good marketing system, with large numbers of supermarkets, and hypermarkets.
7. An educated, aware public, already attuned to shopping in supermarkets and hypermarkets.
8. Literate and modern farmers who have access to technology (radios, TV, magazines, publications, even computers and internet) are open to suggestions and willing to adopt new ideas.
9. The small size of the country offers many advantages, in terms of accessibility to farmers, to produce, to markets. Coupled with the good transport system (good roads, well-maintained vehicles), this can be an important element in the distribution and transportation of fresh organic produce.
10. A good strong economy, stable political situation, and the fairly high purchasing power of the people.
11. Existence of farmers’ co-operatives and associations, which can make any transfer of technology a rapid and effective exercise.
13. Existence of a wealth of indigenous knowledge, which can be tapped for site-specific measures (Facknath and Lalljee, in preparation).
14. A large amount of urban and agricultural wastes, which can be converted into rich compost.
Areas that need to be developed and / or improved:

1. The present trend of excessive pesticide and fertiliser use needs to be changed.
2. Local criteria / standards need to be developed for production, certification, labelling and marketing of organic produce.
3. A system for testing and monitoring organic produce at all stages needs to be set up.
4. Certain areas need to be decreed ‘organic’ to avoid contamination of the organic produce.
5. Good publicity, and right marketing of organic produce, locally, regionally and internationally is required.
6. More research needs to be done in specific areas of organic agriculture.
7. The interest of potential funding bodies, donors and sponsors, such as wholesalers and supermarkets needs to be aroused and encouraged in organic produce and also in R & D in organic farming, (e.g. along the lines of the COOP and MIGROS supermarkets in Switzerland).
8. Proper distribution channels need to be created to ensure fair distribution of profits.
9. A national composting plan for different types of wastes needs to be developed.
10. Appropriate legislation to ensure compliance with all of the above needs to be formulated.

A general belief in Mauritius is that organic agriculture refers to a return to basic, labour-intensive, traditional farming methods, which give low yields, and visually unappealing produce. This is far from the reality of present-day organic farming practices.

Organic farming today can be a highly technology-intensive enterprise, dependent on high-tech, state-of-the-art methods of soil and plant analysis, technical and computerized systems of fertilisation, sophisticated pest and disease control methods based on a thorough understanding of the organisms, the dynamics of the agro ecosystem and strict scientific principles.

It can be less labour-intensive than even the presently used conventional farming systems.

CONCLUSION

Mauritian agriculture is at a crossroads, and recent events have demonstrated very clearly that the country is ready to embark on new ventures. This is absolutely the right moment to launch a new type of agriculture, which can have enormous potential, for the local market, for the tourist industry, as also for export.

The possibility of offering organic food in our luxury hotels and on the inbound and outbound flights to and from Mauritius, for health-conscious tourists and locals, can be a not insignificant plus point for the tourist industry.

The export potential is also huge. Tropical, exotic fruits and vegetables, organically produced, (maybe even out-of-season), can fetch very attractive prices on international markets.

Mauritius already has a considerable number of the pre-requisites any country needs for the development of organic agriculture. The right political will and backing can ensure establishment of the appropriate standards and legislation, as well as the necessary structures for research, development and marketing, and Mauritius can soon be ready to step into the international arena of the world’s healthy, organic market.

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POTENTIAL OF OLFACTORY AND VISUAL BAITS FOR THE CONTROL OF STOMOXYS NIGRA MACQ. (DIPTERA:MUSCIDAE) IN MAURITIUS

D Abeeluck, HB Ghoorbin and T Rawananshah
Agricultural Research and Extension unit

ABSTRACT

The potential of olfactory and visual baits for the control of Stomoxys nigra Macquart was investigated in deer ranches. The cloth trap (Nzi trap) works through the attraction of large blue (pthalogen blue and royal blue) and black objects. Equal numbers of males and females were caught when the pest population was low in the deer ranch. The number of females increased by eight-fold when the pest population was high. No beneficial insects (parasitoids and predators) were recorded in catches. The host odours (octenol, butanone and cow urine) did not increase trap catches. Insecticide-impregnated targets captured very low numbers of S. nigra.

The trap is an environmental-friendly alternative to insecticides against S. nigra. During summer months when S. nigra causes great nuisance to deer, placement of 2 traps (without odour bait) per km$^2$ at sites where deer normally aggregate would help reduce the numbers of S. nigra in ranches.

Key words Stomoxys nigra, Nzi trap, deer, host odours

INTRODUCTION

Two species, Stomoxys nigra Macquart and S. calcitrans L., are present in Mauritius. Stomoxys nigra is predominant and poses a major problem to cattle and deer. The collective blood feeding habit of the adult flies causes bleeding sores resulting into a weight loss in cattle and deer and a reduction in milk production in dairy animals (Moutia 1928, Monty 1972).

Attempts to control S. nigra include the use of insecticides against adult flies (Grose 1976; Galowalia 1975) and biological control agents against larvae and pupae (Greathead and Monty 1982). Other control measures investigated were the sterile insect technique (abandoned because of high cost of its implementation) and physical methods to capture adults (Bourgault Du Coudray 1928; Monty 1972; Monty and Abeeluck 1977).

Traps were used to control stable flies in Mauritius by Bourgault Du Coudray in 1928 but without much success. Farmers used the “Israeli” trap but its efficiency was limited to control flies where animals were stalled (Monty 1972). A funnel trap was designed to capture adults in closed cowbyres and found to be a cheap, easy and unpollutive means for controlling S. nigra (Monty and Abeeluck 1977).

During summer months, the high temperatures cause a seasonal increase in fly activity in the humid and super humid areas. During such periods, the high fly population causes great nuisance to deer. Control of S. nigra in ranches had always been difficult (Monty 1972; Grose 1976; Galowalia 1975). Farmers apply insecticides regularly to control adult fly population. Such a practice gives temporary relief to deer and has adverse effects on the environment and beneficial insects.

Traps have been designed to control Glossina spp. (Diptera: Glossinidae) and have proved to be effective for Stomoxys spp. as well (Flint 1985; Vale & Hall 1985). Cotton cloth dyed with phthalogen blue attracts Stomoxys spp. and host odours (octenol, butanone, acetone and cow urine) in traps increase catches of biting flies (Rugg 1982; Warnes & Finlayson 1985; Halloway & Phelps 1991).

Following the above studies, the International Centre of Insect Physiology and Ecology (ICIPE) has developed a Nzi (Swalili for fly) trap as an environment-friendly alternative to insecticides against
tsetse flies. This trap is made of cotton cloth (phthalogen blue and black) and mosquito nettings. Flies are entrapped by an innovative configuration of cloth and nettings and die from exposure to direct sunlight.

With an aim to controlling adult fly population in ranches, the present study investigated on the efficacy of (1) insecticide-impregnated targets and (2) Nzi trap with and without host odours (octenol, butanone, and cow urine) to lure and kill Stomoxys flies

MATERIALS AND METHODS

All studies were conducted in ranches where the population of S. nigra was a nuisance to deer.

Testing of insecticide-impregnated targets against Stomoxys nigra

The study was carried out in a deer ranch at Salazie in April and October 1999. The insecticide-impregnated target was prepared with a gunny bag (53 cm x 71 cm in size) soaked with 2 litres of citrated bovine blood and treated with Deltamethrin (K-Othrine). The target was stretched between two adjacent trees with binding wire. A plastic sheet was stretched below the target to collect dead flies. The insecticide-impregnated targets were placed at a distance of 1 km from each other at four sites where deer normally feed. The number of dead flies was recorded every 24 hours for 15 consecutive days.

Testing the efficacy of Nzi trap against Stomoxys nigra

The trial was carried out at Salazie between April–October 1999. One Nzi trap was set (at ground level) in an open location at about 10 metres from a feeding site of deer. Catches were collected at 7-10 day intervals to determine the percentage of S. nigra captured and the sex ratio. Between April and June, all insects captured were examined individually to determine the insect species composition of trap catches.

Evaluation of the effect of synthetic host odours and cow urine on trap catches

16 Nzi traps were placed in 4 ranches at Salazie, Sans Souci, Curepipe and Riche en Eau between November 1999 and February 2000. In each ranch, 4 traps were placed at feeding sites of deer at a distance of 1 km from each other. The first trap was baited with octenol, the second with butanone, the third with cow urine and the fourth (control) without any odour bait. Octenol and butanone were dispensed from sealed glass vials (with very fine apertures) at about 0.5 mg / h. 250 ml of cow urine was dispensed from an open glass bottle. All odour sources were placed at ground level. The baits were rotated every 7-10 days and also while catches were collected to avoid environmental factors affecting distribution of S. nigra. Counts on catches at Pradier deer ranch were made during November and December because traps were damaged and could not be replaced.

Choice of colour of trap cloth

In March and April 2000, the effect of visual attraction of S. nigra to cotton cloth dyed phthalogen blue and royal blue was evaluated. One trap (model of ICIPE with cotton cloth dyed phthalogen blue) and the other (model of ICIPE with cotton cloth royal blue in colour) were placed at Salazie. Catches were collected at 6-7 day intervals and the number of S. nigra in both traps was recorded.

RESULTS

Insecticide-impregnated targets to control S. nigra in deer ranches

An average of 10 flies (dead S. nigra) per day was recorded in April and 17 in October.
Insect Species Composition in Catches of Nzi trap

Dipterans constituted the largest proportion of insects (> 90 %) in catches. Individuals from the Diptera were *S. nigra*, *Musca domestica*, (Fam. Muscidae); green and blue bottle flies (Fam. Calliphoridae); fruit flies (Fam. Tephritidae); mosquitoes (Fam. Culicidae) and vinegar flies (Fam. Drosophilidae). Catches of drosophilids and culicids were grouped as “other Dipterans”. Other insects captured were small moths (of uneconomic importance) that were grouped as “Lepidopterans” (*Table 1*). *Stomoxys nigra* was caught in highest numbers (*Tables 1* and *2*). *Musca domestica*, *Lucilia* sp. and *Chrysomyia* sp (green and blue bottle flies), and “other Dipteran” in comparatively lower numbers (*Table 1*). The percentage of “Lepidopterans” varied from 1.5 % to 8.7 %. *Bactrocera cucurbitae*. (fruit flies) was recorded in 2 catches and two individuals of *Apis mellifera* (honeybees) were caught during the whole study.

### Table 1 Percentage of *Stomoxys nigra* and other insect species captured in Nzi trap in the deer ranch at Salazie in April and June 1999

<table>
<thead>
<tr>
<th>Date</th>
<th>Total captures</th>
<th>Stomoxys nigra</th>
<th>Musca domestica</th>
<th>Green bottle fly</th>
<th>Blue bottle fly</th>
<th>unidentified Lepidoptera</th>
<th>Apis mellifera</th>
<th>Bactrocera sp.</th>
<th>Other diptera</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-Apr</td>
<td>653</td>
<td>41.20</td>
<td>14.10</td>
<td>10.70</td>
<td>1.10</td>
<td>1.50</td>
<td>0.10</td>
<td>0.10</td>
<td>31.10</td>
</tr>
<tr>
<td>21-Apr</td>
<td>201</td>
<td>32.00</td>
<td>24.30</td>
<td>5.50</td>
<td>2.00</td>
<td>6.50</td>
<td>0</td>
<td>0</td>
<td>29.60</td>
</tr>
<tr>
<td>22-Apr</td>
<td>314</td>
<td>34.40</td>
<td>15.90</td>
<td>1.00</td>
<td>0.60</td>
<td>7.90</td>
<td>0.30</td>
<td>0</td>
<td>39.80</td>
</tr>
<tr>
<td>26-Apr</td>
<td>863</td>
<td>49.40</td>
<td>15.90</td>
<td>0.70</td>
<td>0.90</td>
<td>6.70</td>
<td>0</td>
<td>0</td>
<td>26.40</td>
</tr>
<tr>
<td>28-Apr</td>
<td>147</td>
<td>51.70</td>
<td>26.50</td>
<td>2.00</td>
<td>1.80</td>
<td>7.40</td>
<td>0</td>
<td>0</td>
<td>10.90</td>
</tr>
<tr>
<td>14-Jun</td>
<td>396</td>
<td>91.20</td>
<td>5.80</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>16-Jun</td>
<td>309</td>
<td>46.00</td>
<td>7.40</td>
<td>1.90</td>
<td>0.00</td>
<td>8.70</td>
<td>0</td>
<td>0.30</td>
<td>35.60</td>
</tr>
<tr>
<td>18-Jun</td>
<td>218</td>
<td>66.50</td>
<td>17.40</td>
<td>4.60</td>
<td>0.00</td>
<td>1.80</td>
<td>0</td>
<td>0</td>
<td>9.60</td>
</tr>
<tr>
<td>21-Jun</td>
<td>274</td>
<td>59.10</td>
<td>15.00</td>
<td>4.70</td>
<td>0.40</td>
<td>4.70</td>
<td>0</td>
<td>0</td>
<td>16.10</td>
</tr>
<tr>
<td>23-Jun</td>
<td>557</td>
<td>75.90</td>
<td>0.00</td>
<td>4.30</td>
<td>1.80</td>
<td>2.00</td>
<td>0</td>
<td>0</td>
<td>16.00</td>
</tr>
</tbody>
</table>

**Percentage of *Stomoxys nigra* and sex ratio**

Between 19 April – 21 October, the percentage of captured *S. nigra* varied from 37.6 % to 99.2 %. The period under study showed 3 distinct phases: Phase I (19/04 – 07/06); Phase II (14/06 – 26/08) and Phase III (02/09 – 21/10).

During phase I, the percentage of caught *S. nigra* ranged from 37.6 % to 49. 2 % (except on 17/5) with a sex ratio (M:F) of 1:1. In phase II, catches of *S. nigra* ranged from 52.5 % to 94.6 % and sex ratio varied from 1:3 to 1:8. In Phase III, up to 99.2 % of the catches were *S. nigra* with a sex ratio ranging from 1: to 1:4 (*Table 2*).

**Catch level**

An average of 92.4 flies was caught daily during April without significant increase in May and June. Between July and September, the daily catch increased to an average of 150 flies per day and reached a peak of 510.5 during October.

Quartiles from cumulated counts over the period were analysed for significant variance. No significant differences were observed among catches by traps with and without baits (P<0.05). The number of *S. nigra* caught in the trap with cotton cloth dyed phthalogen blue did not differ significantly with the numbers in the trap with cotton cloth dyed royal blue.
Table 2  Capture and sex ratio (M : F) of *Stomoxys nigra* Macq. in the Nzi trap in Salazie deer ranch between April May to October 1999.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Period</th>
<th>Captures</th>
<th>Stomoxys nigra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From To</td>
<td>Total</td>
<td>Dipterans* %</td>
</tr>
<tr>
<td>I</td>
<td>19-Apr 26-Apr</td>
<td>2 036 1 066</td>
<td>52 42 1:01</td>
</tr>
<tr>
<td></td>
<td>26-Apr 2-May</td>
<td>905 427</td>
<td>47 49 1:01</td>
</tr>
<tr>
<td></td>
<td>2-May 10-May</td>
<td>1 329 566</td>
<td>43 50 1:01</td>
</tr>
<tr>
<td></td>
<td>10-May 17-May</td>
<td>779 16</td>
<td>2 691 89 1:01</td>
</tr>
<tr>
<td></td>
<td>17-May 24-May</td>
<td>709 342</td>
<td>48 349 49 1:02</td>
</tr>
<tr>
<td></td>
<td>24-May 31-May</td>
<td>1 762 863</td>
<td>49 867 49 1:02</td>
</tr>
<tr>
<td></td>
<td>31-May 7-Jun</td>
<td>668 348</td>
<td>52 302 45 1:03</td>
</tr>
<tr>
<td></td>
<td>7-Jun 14-Jun</td>
<td>953 81</td>
<td>8 860 90 1:02</td>
</tr>
<tr>
<td>II</td>
<td>14-Jun 21-Jul</td>
<td>788 308</td>
<td>39 431 55 1:03</td>
</tr>
<tr>
<td></td>
<td>21-Jun 28-Jul</td>
<td>1 002 335</td>
<td>33 640 64 1:03</td>
</tr>
<tr>
<td></td>
<td>28-Jun 7-Jul</td>
<td>918 372</td>
<td>41 482 53 1:03</td>
</tr>
<tr>
<td></td>
<td>7-Jul 14-Jul</td>
<td>1 306 228</td>
<td>17 1 047 80 1:07</td>
</tr>
<tr>
<td></td>
<td>14-Jul 21-Jul</td>
<td>1 364 195</td>
<td>14 1 129 83 1:08</td>
</tr>
<tr>
<td></td>
<td>21-Jul 28-Jul</td>
<td>979 223</td>
<td>23 707 72 1:03</td>
</tr>
<tr>
<td></td>
<td>28-Jul 4-Aug</td>
<td>959 217</td>
<td>23 674 70 1:08</td>
</tr>
<tr>
<td></td>
<td>4-Aug 11-Aug</td>
<td>1 510 109</td>
<td>7 1 267 84 1:07</td>
</tr>
<tr>
<td></td>
<td>11-Aug 20-Aug</td>
<td>2 265 120</td>
<td>5 2 122 94 1:05</td>
</tr>
<tr>
<td></td>
<td>20-Aug 26-Aug</td>
<td>1 429 63</td>
<td>4 1 346 94 1:04</td>
</tr>
<tr>
<td></td>
<td>26-Aug 2-Sep</td>
<td>557 8</td>
<td>1 538 97 1:02</td>
</tr>
<tr>
<td></td>
<td>2-Sep 10-Sep</td>
<td>541 8</td>
<td>1 522 96 1:02</td>
</tr>
<tr>
<td>III</td>
<td>10-Sep 16-Sep</td>
<td>524 17</td>
<td>3 497 95 1:01</td>
</tr>
<tr>
<td></td>
<td>16-Sep 23-Sep</td>
<td>2 407 60</td>
<td>2 2 342 97 1:03</td>
</tr>
<tr>
<td></td>
<td>23-Sep 29-Sep</td>
<td>1 092 49</td>
<td>4 1 040 95 1:04</td>
</tr>
<tr>
<td></td>
<td>29-Sep 5-Oct</td>
<td>1 669 28</td>
<td>2 1 637 98 1:02</td>
</tr>
<tr>
<td></td>
<td>5-Oct 13-Oct</td>
<td>4 055 24</td>
<td>1 4 042 100 1:02</td>
</tr>
<tr>
<td></td>
<td>13-Oct 21-Oct</td>
<td>6 153 74</td>
<td>1 6 067 99 1:04</td>
</tr>
</tbody>
</table>

*Dipterans included all flies other than *S. nigra*

**Evaluation of the effect of synthetic host odours and cow urine on trap catches**

The Nzi traps, baited with octenol, butanone and cow urine and those without bait captured adult *S. nigra*. Catches of “other Dipterans” and “Lepidopterans” were very low (<1.5 %). Between November 1999 and February 2000, about 53,000, 42,000 and 20,000 adults of *S. nigra* were captured in the 4 traps at Riche en Eau, Sans-Souciand Salazie deer ranches respectively (Figure 1).

At Pradier deer ranch, about 26,200 were caught during November – December (Figure 1).
**DISCUSSION**

The use of targets (gunny bags with citrated bovine blood and insecticides) was not an effective method to lure and kill *S. nigra* in ranches. Four days after exposure, the gunny bags ceased to attract flies and had to be treated regularly.

The Nzi trap was effective in capturing both males and females of *S. nigra* in ranches. Only 2 individuals of *A. mellifera* were recorded on 2 occasions during the whole study and no parasitoids and predators were captured.
Between April and May, catches of *S. nigra* were less than 50 % of the total captures with a sex ratio (M:F) of 1:1 and higher than 90 % between August and October with a sex ratio ranging from 1:1 to 1:7. During July and September, female numbers increased eight-fold.
Males and females occurred in equal numbers when population of *S. nigra* was low during April and May but females became more abundant when there was a seasonal increase in fly activity during July and September.
The use octenol, butanone (synthetic attractants) and cow urine did not significantly improve catches of *S. nigra* when compared among themselves and with the control.

**Practical Implications**

The trap with cotton cloth (royal blue colour) was 50 % less expensive than that with cotton cloth dyed pthalogen blue but equally effective. During the period when there is a seasonal increase in the fly activity, placement of 2 traps (without odour bait) per km² at sites where deer normally aggregate would help reduce the numbers of male and female *S. nigra* in ranches. Maintenance visits are necessary on a weekly basis to check catches. Dead and decaying flies in collecting bags may have a deterrent effect on flies attracted to traps. These collecting bags are to be changed whenever catches are about 1000 or at weekly intervals.

**CONCLUSION**

The Nzi trap is effective in capturing *S. nigra* in deer ranches and can be used in an integrated pest control programme of the pest. It provides a cheap method to reduce the intensity of *S. nigra* attack on deer in ranches during summer months. Its efficacy in the vicinity of cow byres against the pest is being investigated.

**Future Research**

The following lines of research have been identified: (i) improvement of the design of the trap to withstand the adverse climatic conditions. After 6 weeks of exposure to the sun, the cloth on the trap lost its brightness and had yellow-grey tints. The trap is vulnerable to damage during windy days or during cyclonic weather, (ii) investigation whether synthetic host-odours play a role in host-location by *Stomoxys*, and (iii) evaluation of the impact of mass trapping of flies in ranches.

The trap can be a useful tool in dispersal studies of *S. nigra*.

**ACKNOWLEDGMENTS**

We are grateful to Dr R. Sani of the ICIPE (Nairobi) who provided a sample of the Nzi trap, and Mr. R. Ramnauth, Biometrician, for his assistance in analytical work. We also extend our gratitude to Mauritius Research Council for funding the work partially and to members of the Mauritius Meat Producers’ Association who provided facilities to conduct the research.

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LUTTE INTEGREE CONTRE LES RAVAGEURS DES CULTURES MARAICHERES A LA REUNION

Philippe Ryckewaert et Frédéric Fabre
CIRAD-3P, Saint Pierre, La Réunion

RESUME
Les cultures maraîchères à la Réunion sont fréquemment soumises aux attaques de plusieurs insectes et acariens ravageurs comme les aleyrodes, les chenilles ou les mouches des légumes. La lutte chimique classique ayant montré ses limites, il devient indispensable de s’orienter vers d’autres méthodes comme la lutte intégrée. Un suivi de diverses parcelles expérimentales montre que des auxiliaires peuvent limiter le développement de certains ravageurs en combinaison avec une lutte chimique raisonnée. Toutefois la lutte contre d’autres insectes nuisibles nécessite la mise au point de méthodes basées sur l’attractivité de substances ou de pièges, et sur le développement de la lutte biologique.

Mots Clés: lutte intégrée, entomologie, lutte chimique, lutte biologique, cultures maraîchères, Réunion

INTRODUCTION
Les insectes et acariens ravageurs, ainsi que les maladies qu’ils transmettent, provoquent souvent des dégâts importants sur les cultures maraîchères, notamment dans les zones tropicales. Les producteurs utilisent généralement de façon massive et répétée un certain nombre d’insecticides et acaricides dont l’utilisation entraîne de nombreux problèmes: coût en produits et main d’œuvre, risques de résidus dans les parties consommées, pollution de l’environnement, élimination des organismes utiles et apparition de résistances aux pesticides.

De nouvelles méthodes de lutte contre les ravageurs se développent en privilégiant une gestion durable des populations d’insectes et acariens tout en évitant des dégâts économiques et en préservant l’environnement et la santé humaine. Ces méthodes s’inscrivent dans un cadre appelé lutte intégrée combinant une lutte chimique raisonnée, la lutte biologique, des moyens biotechniques et des mesures prophylactiques.

A la Réunion, un programme récent de recherches et d’expérimentations sur certains aspects de la lutte intégrée a été mis en place.

La lutte intégrée contre les ravageurs
La limitation des populations de ravageurs peut se faire par des méthodes complémentaires (Ryckewaert, 1998):
- respect de la prophylaxie au niveau de l’exploitation : protection de la pépinière, choix des parcelles par rapport au vent, élimination des vieilles cultures, vide sanitaire, choix de variétés bien adaptées, bonne conduite des plantes (irrigation, fertilisation, désherbage…);
- lutte chimique raisonnée par le choix du moment d’application (seulement quand les populations d’un ravageur deviennent trop importantes) et par le choix de pesticides les plus inoffensifs possibles pour les auxiliaires. Il convient également de respecter les doses prescrites, le mouillage pour une surface donnée, les délais d’emploi des produits avant récolte et d’alterner les familles chimiques de pesticides pour éviter les phénomènes d’accoutumance.
- lutte biologique: réalisée par les auxiliaires (prédateurs, parasitoïdes, entomopathogènes) soit naturels soit introduits dans la culture. N’est possible que si la lutte chimique est raisonnée;
- moyens biotechniques: basés sur le comportement de certains insectes qui sont attirés par différents attractifs visuels (couleur) ou olfactifs (aliments, phéromones…). Ces couleurs et
ces substances peuvent être utilisées pour du piègeage de masse, du piègeage d’avertissement ou des traitements par taches.

### Les principaux ravageurs et auxiliaires à la Réunion


Les prédateurs sont essentiellement des punaises (Miridae, Anthocoridae), des coccinelles et des syrphes. Les hyménoptères parasitoïdes sont largement répandus chez les aleurodes, les pucerons, les mouches mineuses et les chenilles. Les entomopathogènes sont présents mais restent encore peu étudiés.

La diversité climatique de la Réunion a permis le développement d’insectes d’origine tropicale aussi bien que d’origine tempérée, tandis que son insularité a entraîné la présence d’espèces endémiques (à l’île ou à la région).

### ETUDES ENGAGEES A PARTIR DE 2000

La mise au point de méthodes de lutte doit d’abord se baser sur des connaissances bio-écologiques des ravageurs concernés. Dans un premier temps, nous nous sommes focalisés sur les ravageurs suivants: aleurodes, teigne du chou et mouches des légumes.

#### Aleurodes


Afin de suivre la dynamique des populations des deux principales espèces d’aleurodes et de leurs parasitoïdes, des parcelles de tomate ont été mises en place. Dans un premier essai, une parcelle de 700 m² plantée début février est partagée en deux moitiés, l’une subissant un traitement hebdomadaire avec des insecticides à large spectre, l’autre restant sans traitements. Les aleurodes sont comptés chaque semaine sur des panneaux jaunes englués tandis que des prélèvements de feuilles avec des nymphes permettent d’estimer le taux de parasitisme. Les observations montrent une augmentation des populations d’aleurodes et de mouches mineuses sur la partie traitée alors qu’elles diminuent sur l’autre partie un mois et demi après la plantation. Les taux de parasitisme dépassent 80 % sur la partie sans traitements alors qu’ils atteignent à peine 40 % sur la moitié traitée. Un prélèvement à l’aspirateur mécanique D-Vac de l’entomofaune présente montre que les parasitoïdes d’aleurodes sont dix fois plus nombreux en l’absence de traitements. Ces observations démontrent l’intérêt de la lutte biologique naturelle contre les aleurodes et d’autres ravageurs en l’absence de traitements sélectifs.

Un autre essai a permis d’évaluer les fluctuations de populations d’aleurodes sur une culture de tomate sous serre fermée. Des lâchers d’*Encarsia formosa* sont effectués chaque semaine pendant 3 mois et les traitements sont raisonnés en fonction de l’apparition de pics de populations. Le cycle de cultures s’est déroulé sur 9 mois et seuls 3 traitements ont été réalisés contre les aleurodes (essentiellement *B. tabaci*) avec un nouveau produit spécifique, l’ADMIRAL ® (pyriproxifène). Les populations d’aleurodes ont montré quelques développements périodiques, en particulier suite à l’arrêt des lâchers.
d’*Encarsia* en fin de cycle, mais aucun dégâts n’est observé. L’ADMIRAL semble avoir une certaine efficacité sur les larves des deux espèces d’aleurodes. Le taux de parasitisme a dépassé 80 % sur *B. tabaci*.


D’autres études sur les aleurodes et les virus qu’ils transmettent sont menées par différentes équipes au CIRAD: connaissance de la variabilité du TYLCV transmis par *Bemisia*, caractérisation des biotypes de *Bemisia*, fluctuations spatio-temporelles des populations, évaluation des niveaux de résistance de variétés de tomate au TYLCV.

**Teigne du chou**

La teigne du chou (*Plutella xylostella*) constitue de loin le plus important ravageur des choux, malgré la présence de parasitoïdes (Guilloux, 2000). La dynamique des populations de la teigne et de ses parasitoïdes est étudiée sur plusieurs parcelles de chou non traitées situées à différentes altitudes. Pour cela on réalise des prélèvements hebdomadaires de plants où sont comptés les chenilles et les cocons de teigne. Les larves des derniers stades et les cocons sont conservés deux semaines en l’attente des sorties de teignes, des parasitoïdes et des hyperparasites. Les populations de teigne augmentent généralement de façon importante après un mois de culture, atteignant 40 chenilles par plant et par semaine. Les taux de parasitisme varient de 10 % en zone cannière à 45 % dans les zones maraîchères, mais les dégâts restent toujours importants. Les populations de parasitoïdes suivent une évolution comparable à celle de la teigne. *Diadegma mollipla* est le parasitoïde le plus abondant en altitude alors que *Cotesia plutella* est plus fréquent à basse altitude. D’autres parasitoïdes, des hyperparasites et des prédateurs (syrphes) sont présents mais en très faible nombre. Sur une des parcelles, la moitié a été traitée chaque semaine avec des insecticides à large spectre : les populations de *Plutella* n’ont pas été affectées mais les choux ont été protégés des attaques de la pyrale (*Crocidolomia pavonana*). On note cependant des taux de parasitisme équivalents dans les deux parties.

Nous avons ensuite comparé sur un autre essai l’évolution des populations entre une partie témoin sans traitements et une partie recevant un programme de traitements raisonnés contre les chenilles. Dans ce cas on applique un BATIK ® (*B. thuringiensis*) toutes les 2 semaines en alternance avec ZOLONE ® (phosalone) ou TECHNUFAN ® (endosulfan) l’autre semaine (ces 2 produits sont assez peu toxiques sur les auxiliaires). Les populations de *Plutella* sont à des niveaux comparables durant le cycle de culture sauf près de la récolte où l’on assiste à une forte augmentation des populations sur la partie traitée. Nous n’expliquons pas ce fait d’autant que les taux de parasitisme sont équivalents dans la partie traitée (10 %) et dans le témoin (9 %). Ainsi les traitements se sont avérés inutiles dans ce cas, d’autant que les dégâts ont été importants (respectivement 58 et 61 % de rebut).

Nous avons enfin testé un filet anti-insecte (protection mécanique) sur quelques plants pour éviter les pontes d’adultes sur les feuilles. La protection s’avère insuffisante, les teignes finissant par se développer à l’intérieur. D’autre part, la croissance des choux est perturbée ainsi que la coloration des feuilles. Enfin le coût de ce système reste élevé.

**Mouches des légumes**

La mouche de la tomate et les mouches des cucurbitacées provoquent des dégâts importants sur ces cultures et ne sont que partiellement maîtrisées par les traitements insecticides (Brévault, 1999; Vayssières, 1999). Ces derniers n’étant pas sélectifs, le développement d’une lutte intégrée sur ces cultures passe par la mise au point de méthodes « douces » pour limiter les populations de mouches des légumes. A l’exemple des méthodes utilisées en arboriculture contre les mouches des fruits, nous
tentons de définir des moyens biotechniques basés sur l’attractivité visuelle ou olfactive de différents pièges combinés ou non avec des substances chimiques.

Concernant la mouche de la tomate, deux types de pièges ont été disposés dans une parcelle:

- 2 pièges constitués d’une sphère creuse orangée engluée et contenant un broyat de fruits verts de bringélier (*Solanum mauritanum*). L’attractivité est à la fois visuelle et olfactive, le système étant senti attirer les femelles (site de ponte);
- 2 pièges de type « Téphri-Trap » contenant du TORULA®. Il s’agit d’un piège olfactif de type alimentaire.

Ces pièges doivent alerter sur l’arrivée des mouches tout en les quantifiant, mais ne constituent pas des dispositifs de lutte directe de piégeage de masse. Ces avertissements permettraient de déclencher de façon raisonnée les traitements. Les résultats sont très insuffisants: on compte au maximum 16 mouches par semaine pour 2 sphères et au plus 9 pour les 2 autres pièges, alors que les fruits ont été sévèrement touchés (36 % des premiers fruits verts atteints). Il est possible que l’attractivité de la culture soit supérieure à celle des pièges. Des traitements chimiques avec KLARTAN® (tau-fluvanlate), ZOLON® et VERTIMEC® (abamectine) n’ont pas permis de diminuer les dégâts par la suite (jusqu’à 18 % de fruits en récolte perdus), et nous constatons par ailleurs une augmentation des populations d’aleurodes et de mouches mineuses (par élimination des auxiliaires?).

Le traitement par taches est une technique utilisée en arboriculture qui consiste à traiter une partie de certains arbres avec un mélange insecticide + attractif alimentaire (Epsky et al., 1994; Liu & Chen, 1995; Tamori & Iraha, 1986). On utilise ainsi moins de produit par surface et on préserve une partie des auxiliaires. Cette technique peut être appliquée aux cultures maraîchères à condition d’avoir des attractifs efficaces sur les mouches concernées. Nous avons ainsi en un premier temps testé en conditions semi-contrôlées (grandes cages extérieures) plusieurs attractifs du marché à différentes concentrations sur la mouche du melon (*B. cucurbitae*). Les produits testés sont le BUMINAL®, le NULURE®, le SOLBAIT®, l’HYMLURE®, le CORN STEEP WATER® et le PINNACLE®. Les gammes de concentration s’échelonnent de 0,5 à 10 %. Les taux de captures des mâles et des femelles augmentent avec la concentration sauf pour le BUMINAL où il reste constant. La comparaison des attractifs entre eux (à une concentration donnée) afin de déterminer les plus intéressants montre une meilleure efficacité pour le SOLBAIT, suivi du PINNACLE, du CORN STEEP WATER, du NULURE et de l’HYMLURE. Une expérimentation au champ doit confirmer les résultats obtenus en cage.

**Autres ravageurs**

Sur tomate, les chenilles de la noctuelle *Heliothis armigera* causent des dégâts parfois importants sur les fruits, notamment en l’absence d’insecticides. La régulation naturelle n’a pas été étudiée mais semble très insuffisante.

Les mouches mineuses sont très présentes sur tomate mais sont généralement bien parasitées en l’absence de traitements chimiques classiques.

Les thrips et notamment *Frankliniella occidentalis* (vecteur du TSWV) sont restés peu nombreux sur nos essais.

Les pucerons (surtout *Aphis gossypii*) posent des problèmes essentiellement sur cucurbitacées par les viroses qu’ils transmettent. Des populations semblent résistantes au PIRIMOR® (pirimicarbe), aphicide conseillé en lutte intégrée.

Les acariens tétranyques (araignées rouges) peuvent pulluler à certaines périodes.

**CONCLUSION**

Les premières expérimentations menées à la Réunion montrent l’intérêt de la lutte biologique naturelle associée à une lutte chimique raisonnée pour limiter les populations de ravageurs des cultures maraîchères. Cependant certains d’entre eux sont mal contrôlés par ces moyens (chenilles, mouches...)
des légumes...) et il sera nécessaire de mettre au point d’autres techniques complémentaires comme l’utilisation de divers attractifs ou l’introduction de nouveaux auxiliaires. Pour cela, la connaissance de la biologie et des comportements des insectes devra être approfondie. Enfin le développement de ces méthodes ne pourra se réaliser qu’en coopération avec les organismes locaux et régionaux impliqués dans cette démarche.

BIBLIOGRAPHIE


ETUDE COMPAREE DE LA BIOLOGIE DU DEVELOPPEMENT CHEZ TROIS ESPECES DE MOUCHES DES FRUITS (CERATITIS SPP.) (DIPTERA : TEPHRITIDAE), NUISIBLES AUX CULTURES FRUITIERES A LA REUNION

Pierre-François Duyck et Serge Quilici

CIRAD-FLHOR, Ile de La Réunion

RESUME

A La Réunion, les mouches des fruits (Diptera : Tephritidae) constituent les principaux ravageurs des cultures fruitières. Le développement et la survie de la mouche méditerranéenne des fruits, Ceratitis capitata (Wiedemann), de la mouche du Natal, C. rosa (Karsch) et de la mouche des Mascareignes, C. catoirii Guérin-Mèneville sont comparés à 5 températures constantes de 15 à 35°C. Les seuils minimums de développement et les constantes thermiques ont pu être calculés par le modèle des sommes de température. Les espèces diffèrent notamment au stade larvaire et peu au stade embryonnaire. C. rosa semble plus adaptée aux basses températures que les deux autres espèces. Globalement C. catoirii possède une survie faible sur l'ensemble de la gamme de température étudiée. La distribution des trois Ceratitis sur l'île peut être partiellement expliquée par la réponse différentielle des espèces à la température. D'un point de vue appliqué, les résultats obtenus serviront à optimiser les élevages au laboratoire. Ils contribueront en outre, dans un proche avenir, aux études conduites sur la modélisation des populations de mouches des fruits.

Mots clés: Diptera, Tephritidae, Ceratitis, mouches des fruits, température, développement, survie

INTRODUCTION

Les mouches des fruits (Diptera : Tephritidae) causent des dégâts importants sur les cultures fruitières et maraîchères à La Réunion. Ainsi, trois espèces du genre Ceratitis s'attaquent aux cultures fruitières:

- la mouche méditerranéenne des fruits ou cératite, C. capitata, qui est surtout abondante dans les zones sèches de basse altitude,
- la mouche du Natal, C. rosa, qui constitue l'espèce la plus nuisible; très polyphage, elle est largement répandue dans l'île, du niveau de la mer jusqu'à 1500 m d'altitude
- et C. catoirii, espèce endémique des Mascareignes, qui est surtout présente en zones humides de basse altitude.

Si de nombreux travaux ont été réalisés sur la cératite, dans divers pays du monde, la mouche du Natal a encore été à ce jour très peu étudiée, malgré sa grande importance dans de nombreux pays africains. La biologie de C. catoirii est encore totalement inconnue. L'importance relative de ces espèces dans les diverses zones de l'île est fonction de la compétition inter-spécifique, modulée par les facteurs intrinsèques (potentiel biotique des espèces) ou extrinsèques (climat, nature et abondance des plantes hôtes...). La présente étude vise à préciser l'influence de la température sur la durée de développement et la survie des différents stades pré-imaginaux.

MATERIELS ET METHODES

Le temps requis pour qu'au moins 50% des individus d'un stade donné complètent leur développement est déterminé aux températures constantes suivantes (± 1°C) : 15, 20, 25, 30 et 35°C.

**Stade embryonnaire**

Pour la collecte des œufs, un pondoir artificiel est placé dans la cage d'élevage pendant une période de 2 heures. On place 100 œufs collectés au hasard à l'aide d'un pinceau fin, sur un papier buvard sombre imbibé d'une solution de nipagine / benzoate de soude (2 g +2 g / l), disposé dans une boîte de Pétri. Les œufs sont inspectés toutes les 2 heures sous la loupe binoculaire, afin de déterminer le moment de leur éclosion. On effectue 4 répétitions pour chaque essai.

**Stades larvaires**

Les jeunes larves (L1) sont collectées juste après l'éclosion de l'œuf, à l'aide d'un pinceau fin. Le prélèvement des jeunes larves s'effectue au cours d'une période de 2 heures. On place ainsi 100 jeunes larves collectées au hasard, dans une petite boîte contenant un milieu larvaire N°1 adapté pour C. capitata et C. rosa (Etienne, 1973) (**Tableau 1**). C. catoirii est élevée sur les mêmes milieux que C. rosa. On effectue 4 répétitions pour chaque essai. Au bout de quelques jours, les larves plus âgées sont ensuite transférées dans une boîte contenant du milieu N° 2 et du son, elle-même placée dans une cuvette plastique dont le fond est garni d'une couche de sable (sec pour C. capitata ; humidifié pour C. rosa et C. catoirii).

En fin de développement larvaire, le sable des cuvettes est tamisé soigneusement et délicatement 3 fois par jour, afin de prélever les jeunes pupes juste après leur formation. On note pour chaque lot l'intervalle de temps au cours duquel a lieu la pupaison.

**Tableau 1** Composition des milieux larvaires pour Ceratitis capitata et Ceratitis rosa (d'après Etienne, 1973).

<table>
<thead>
<tr>
<th>Composition</th>
<th>Unité</th>
<th>Ceratitis capitata</th>
<th>Ceratitis rosa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Milieu 1</td>
<td>Milieu 2</td>
</tr>
<tr>
<td>Poudre de carotte déshydratée</td>
<td>g</td>
<td>56</td>
<td>50</td>
</tr>
<tr>
<td>Levure de bière</td>
<td>g</td>
<td>52</td>
<td>75</td>
</tr>
<tr>
<td>Sucre</td>
<td>g</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Pomme de terre déshydratée</td>
<td>g</td>
<td>90</td>
<td>12.5</td>
</tr>
<tr>
<td>Eau + Nipagine + Benzoate</td>
<td>ml</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>HCl a 16.5 p mille</td>
<td>ml</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Agar</td>
<td>g</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Germe de blé</td>
<td>g</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

**Stade nymphal**

Les jeunes pupes sont collectées par tamisage doux juste après leur formation. Le prélèvement des jeunes pupes s'effectue au cours d'une période de 2 heures. On place 100 jeunes pupes collectées au hasard dans une petite boîte cylindrique contenant une éponge d'épaisseur 5 mm légèrement humidifiée. On effectue 4 répétitions pour chaque essai. En fin de développement pupal, les émergences sont observées 3 fois par jour, en déterminant pour chacune d'elles l'intervalle de temps au cours duquel a eu lieu l'émergence.

**Modèle des sommes de températures**

Cette approche est basée sur l'hypothèse qu'au-dessus d'une certaine température-seuil de développement, la relation entre température et taux de développement est linéaire. Ainsi un nombre
constant d'unités de température (généralement exprimé en degrés-jours) au-dessus de ce seuil est nécessaire pour compléter le développement (Wagner et al. 1984; Fletcher, 1989). Pour établir cette relation, la durée de développement des différents stades (i.e. le temps requis pour qu'au moins 50% des individus accomplissent leur développement) est déterminée pour une série de températures constantes au laboratoire. Le taux de développement (100 / temps de développement) est ensuite calculé pour chaque température. La température-seuil de développement, \( t \) (la température au-dessous de laquelle le développement est nul) est alors déterminée par extrapolation. La constante \( K \) (le nombre de degrés-jours au-dessus de la température seuil requis pour compléter le développement), est calculée à partir de l'équation de régression, en utilisant la relation \( y = K / (x - t) \) (Fletcher, 1989). Par ailleurs, nous déterminerons pour chaque stade l'étendue du temps de développement (Etendue = max [temps de développement] – min [temps de développement], i.e., le laps de temps entre la première et la dernière éclosion, entre la première et la dernière pupaison ou entre la première et la dernière émergence).

**Taux de survie**

Le taux de survie des différents stades est déterminé en divisant le nombre d'individus en vie à la fin d'un stade donné par le nombre d'individus initial. Ainsi, le nombre final d'adultes obtenus à partir d'un lot de 100 œufs est calculé comme le produit des taux de survie des différents stades depuis l'œuf jusqu'à l'adulte. Par ailleurs, le taux de mortalité instantané (\( = -\ln [\text{taux de survie}] / \text{temps de développement} \)) est calculé (van Rijn et al. 1995).

**Analyses statistiques**

Les tests de développement sont répétés 4 fois pour chaque stade immature. Les données sont analysées selon un dispositif en blocs randomisés, en considérant les répétitions comme de multiples observations pour chaque température étudiée. Des analyses de la variance (ANOVA) sont réalisées pour analyser les effets des traitements sur les paramètres mesurés. Les moyennes sont ensuite comparées lorsqu'il est nécessaire par un test de Student Newman-Keuls (\( P = 0.05 \)) (StatSoft-France, 1997).

**RESULTATS**

**Relation température - taux de développement pour chaque espèce**

Dans la gamme de température allant de 15 à 30°C, un modèle linéaire de relation entre température et développement est établi. Pour *C. capitata*, une très forte relation linéaire est observée entre température et taux de développement (\( R^2 \geq 0.98 \)) (Figure 1). La température en dessous de laquelle le développement est nul est calculée grâce à l'équation de régression pour chaque stade. Les températures-seuils de 11.6, 10.2 et 11.2 °j pour les œufs, les larves et les pupes, respectivement, ont été déterminées. La constante thermique en degrés-jours est de 28.1, 88.8 et 142.7 °j, respectivement, pour les œufs, les larves et les pupes. Pour *C. rosa*, le modèle linéaire est établi entre 15 et 30°C pour les stades (Figure 1). Le coefficient de corrélation linéaire est élevé pour les œufs et les pupes (\( R^2 \geq 0.98 \)) et plus faible pour les larves (\( R^2 = 0.88 \)). La température-seuil calculée pour les œufs, les larves et les pupes, est de 9.8, 3.1, et 11.0 °C respectivement. La constante thermique est de 35.3, 223.2 et 146.9 °j respectivement, pour les œufs, les larves et les pupes. Entre 15 et 30°C, la relation température - taux de développement est fortement linéaire (\( R^2 \geq 0.98 \)) chez *C. catioiri* (Figure 1). Le seuil minimum de développement théorique calculé pour les œufs, les larves et les pupes est de 9.9, 8.9 et 9.2°C respectivement. La constante thermique est de 35.1, 126.5 et 194.0 °j respectivement, pour les œufs, les larves et les pupes.
Figure 1  Relation entre température et taux de développement (100 par jour) pour les différents stades immatures chez *C. capitata*, *C. rosa*, *C. catorii*.
Comparaison interspécifique des taux de survie (Tableau 2)

Pour le stade embryonnaire, de 15 à 25°C, C. catoirii a une survie significativement moins bonne que celle de C. capitata et C. rosa (F = 35.3, df = 2, P < 0.01), elle possède en effet des taux de mortalité instantanés élevés. A 30°C, c'est C. rosa qui présente une mortalité plus importante. A 35°C, aucun œuf n’a éclaté toutes espèces confondues.

Tableau 2 Comparaison de la survie des stades immatures entre C. capitata, C. rosa et C. catoirii à une série de températures constantes (n = 4 répétitions).

<table>
<thead>
<tr>
<th>Stade</th>
<th>Espece</th>
<th>15 °C</th>
<th>20 °C</th>
<th>25 °C</th>
<th>30 °C</th>
<th>35 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moy %</td>
<td>MI</td>
<td>Moy %</td>
<td>MI</td>
<td>Moy %</td>
<td>MI</td>
</tr>
<tr>
<td>Embryonnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. capitata</td>
<td>92 ± 5 b</td>
<td>0.01</td>
<td>81 ± 2 a</td>
<td>0.06</td>
<td>96 ± 2 a</td>
<td>0.02</td>
</tr>
<tr>
<td>C. rosa</td>
<td>88 ± 6 b</td>
<td>0.02</td>
<td>80 ± 1 a</td>
<td>0.07</td>
<td>91 ± 6 a</td>
<td>0.04</td>
</tr>
<tr>
<td>C. catoirii</td>
<td>68 ± 7 b</td>
<td>0.05</td>
<td>67 ± 6 b</td>
<td>0.12</td>
<td>60 ± 7 b</td>
<td>0.24</td>
</tr>
<tr>
<td>Larvaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. capitata</td>
<td>89 ± 7 a</td>
<td>0.01</td>
<td>85 ± 10 a</td>
<td>0.02</td>
<td>96 ± 2 a</td>
<td>0.01</td>
</tr>
<tr>
<td>C. rosa</td>
<td>69 ± 9 b</td>
<td>0.02</td>
<td>54 ± 9 b</td>
<td>0.06</td>
<td>87 ± 4 b</td>
<td>0.01</td>
</tr>
<tr>
<td>C. catoirii</td>
<td>54 ± 4 b</td>
<td>0.03</td>
<td>77 ± 1 b</td>
<td>0.02</td>
<td>66 ± 1 c</td>
<td>0.06</td>
</tr>
<tr>
<td>Pupal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. capitata</td>
<td>84 ± 9 a</td>
<td>0.01</td>
<td>95 ± 1 a</td>
<td>0.01</td>
<td>79 ± 6 b</td>
<td>0.02</td>
</tr>
<tr>
<td>C. rosa</td>
<td>91 ± 3 b</td>
<td>0.01</td>
<td>88 ± 7 a</td>
<td>0.01</td>
<td>95 ± 4 a</td>
<td>0.01</td>
</tr>
<tr>
<td>C. catoirii</td>
<td>50 ± 26 b</td>
<td>0.02</td>
<td>74 ± 1 b</td>
<td>0.02</td>
<td>74 ± 8 b</td>
<td>0.02</td>
</tr>
</tbody>
</table>

MI : taux de mortalité instantané (= - ln (survive) / temps de développement).
Pour un stade donné, les moyennes suivies de lettres différentes dans une même colonne sont significativement différentes (ANOVA et test de Student Newman-Keuls, P < 0.05).

Pour les stades larvaires, C. capitata est la seule espèce qui ait survécu à 35°C mais avec 95% de mortalité. Pour toutes les autres températures, C. capitata a une survie supérieure aux deux autres espèces sauf à 20°C où sa survie est équivalente à celle de C. catoirii. A 30°C, la survie de C. rosa apparaît très faible par rapport aux autres espèces avec une mortalité instantanée élevée. Il a été observé qu'une mortalité importante a lieu pendant la phase de pré-pupe; en effet à 30°C pour C. rosa, en moyenne 50 larves ont sauté dans le sable alors que la survie moyenne est de 23%.

Pour le stade pupal, à 35°C, la mortalité est de 100% pour les trois espèces. Globalement, pour les températures comprises entre 15 et 30°C, C. catoirii possède une survie significativement moins importante que C. rosa et C. capitata (F = 13.2, df = 2, P < 0.01) mais pas différente de celle de C. capitata à 25°C. A 15 et 20°C, la survie des pupes ne diffère pas significativement entre C. rosa et C. capitata tandis qu'à 25°C, la survie de C. rosa est meilleure et à 30°C nettement moins bonne que celle de C. capitata. Les mortalités instantanées les plus importantes du stade pupal sont enregistrées pour C. catoirii et C. rosa à 30°C.

Comparaison interspécifique des temps de développement (Tableau 3)

Pour la durée du développement embryonnaire, on trouve des différences significatives entre espèces pour chaque température sauf à 15°C. A 20°C, C. capitata montre un développement embryonnaire un peu plus long que C. rosa et C. catoirii tandis qu'elle se développe plus rapidement que ces deux dernières à 25 et 30°C. L'étendue du temps de développement n'est pas différente entre les espèces sauf à 30°C où elle est plus faible pour C. capitata que pour les deux autres. Le C.V. de l'étendue du développement embryonnaire ne varie pas non plus entre les trois espèces sauf à 25°C, où il apparait significativement plus faible pour C. rosa.

Dans la gamme de 15 à 30°C, C. capitata présente un temps de développement larvaire significativement moins long que les deux autres espèces. Les temps de développement de C. rosa et
de *C. catoirii* ne diffèrent pas entre eux à 15 et 20°C alors que *C. catoirii* a un développement larvaire plus rapide que *C. rosa* à 25 et 30°C. À 25 et 30°C, l'étendue du temps de développement larvaire diffère significativement entre les trois espèces: *C. rosa* possède l'étendue la plus longue, *C. catoirii* possède une étendue moyenne et *C. capitata* possède l'étendue la plus courte (inférieure ou égale à 2 jours). Le C.V. de l'étendue important chez ces deux dernières espèces indique que l'étendue est grande par rapport au temps de développement.

À 15°C, il n'y a pas de différence significative entre les durées de développement pupal des trois espèces. Le temps de développement de *C. catoirii* est plus long que ceux de *C. rosa* et *C. capitata* entre 20 et 30°C. L'étendue et le C.V. de l'étendue de *C. capitata* sont plus faibles que ceux des deux autres espèces à 30°C.

**Tableau 3** Comparaison des temps de développement des stades immatures entre *C. capitata*, *C. rosa* et *C. catoirii* à une série de températures constantes (n = 4 répétitions)

<table>
<thead>
<tr>
<th>Stade</th>
<th>Espece</th>
<th>15 °C</th>
<th>20 °C</th>
<th>25 °C</th>
<th>30 °C</th>
<th>35 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moy</td>
<td>Etend</td>
<td>CV</td>
<td>Moy</td>
<td>Etend</td>
<td>CV</td>
</tr>
<tr>
<td>embryonnaire hrs</td>
<td><em>C. capitata</em></td>
<td>187 ± 8</td>
<td>94 ± 50</td>
<td>50</td>
<td>84 ± 3</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td><em>C. rosa</em></td>
<td>184 ± 9</td>
<td>90 ± 49</td>
<td>49</td>
<td>80 ± 1</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td><em>C. catoirii</em></td>
<td>188 ± 7</td>
<td>99 ± 53</td>
<td>53</td>
<td>80 ± 1</td>
<td>45</td>
</tr>
<tr>
<td>larvaire jours</td>
<td><em>C. capitata</em></td>
<td>21 ± 0.4</td>
<td>5</td>
<td>24</td>
<td>8 ± 0.1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>C. rosa</em></td>
<td>23 ± 0.6</td>
<td>7</td>
<td>29</td>
<td>11 ± 0.1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>C. catoirii</em></td>
<td>22 ± 0.6</td>
<td>5</td>
<td>23</td>
<td>11 ± 1.3</td>
<td>6</td>
</tr>
<tr>
<td>pupal jours</td>
<td><em>C. capitata</em></td>
<td>35 ± 0.4</td>
<td>3</td>
<td>9</td>
<td>17 ± 0.6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><em>C. rosa</em></td>
<td>35 ± 0.6</td>
<td>4</td>
<td>10</td>
<td>16 ± 0.2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><em>C. catoirii</em></td>
<td>36 ± 2.1</td>
<td>3</td>
<td>8</td>
<td>17 ± 0.1</td>
<td>4</td>
</tr>
</tbody>
</table>

Etendue moyenne = max [temps de développement] – min [temps de développement], (le laps de temps entre la première et la dernière éclosion d’œuf, entre la première et la dernière pupaison ou entre la première et la dernière émergence d'adulte).

Coefficient de variation moyen, C.V. = [100 x étendue] / [temps de développement].

Pour un stade donné, les moyennes suivies de lettres différentes dans une même colonne sont significativement différentes (ANOVA et test de Student Newman-Keuls, P < 0.05).

**DISCUSSION**

**Implications physiologiques:**

La survie de tous les stades de *C. capitata* est élevée dans la gamme 15-30°C (> 75%) ce qui est conforme aux études précédentes conduites à températures modérées (Messenger & Flitters, 1958; Crovetti et al. 1986; Delrio et al. 1986; Vargas et al. 1996). Les temps de développements, de l’œuf à l’adulte, de *C. capitata* se situent entre 16 et 64 jours, respectivement entre 30 et 15°C. Ces résultats pour les stades immatures sont généralement en accord avec la littérature (Messenger & Flitters, 1958; Tassan et al. 1983; Crovetti et al. 1986; Delrio et al. 1986; Vargas et al. 1996).

Les valeurs de la température-seuil et de la constante thermique sont également en accord avec les études antérieures sauf pour le stade larvaire. A Hawaii, Vargas et al. (1996) ont estimé un seuil thermique de 5.2°C et une constante thermique de 138.7°C pour le stade larvaire de *C. capitata*, en
utilisant également le modèle linéaire et en travaillant sur une gamme de températures constantes (16-32°C) proche de la notre. Ces différences importantes peuvent résulter de l'utilisation de milieux artificiels d'élevage différents, de la souche utilisée ou encore de conditions d'élevage différentes. Ces auteurs reconnaissent toutefois que la température-seuil pour le développement larvaire a sans doute été sous-estimée dans leur travail. Le temps de développement larvaire à basse température aurait peut-être été faussé par le comportement des cohortes : les larves s'agglutinaient à la base de la boîte de milieu, probablement pour rechercher de la chaleur. En effet, les hautes densités de larves dans les milieux peuvent produire de hauts niveaux de chaleur métabolique (Tanaka et al. 1972; Hooper, 1978). Ce comportement n'a pas été observé dans notre étude du fait de l'utilisation d'une faible densité de larves par boîte de milieu. De plus, la valeur de température-seuil calculée par Tassan et al. (1983) ($t = 9.7°C$), qui ont étudié les œufs et les larves comme un seul stade, conforte notre résultat. Il serait toutefois intéressant de compléter nos données par des études complémentaires réalisées à des températures plus faibles, proches du seuil de développement, en utilisant des modèles non-linéaires.

Aucune publication n'a été réalisée sur le développement de *C. rosa* à différentes températures. La survie de *C. rosa* est nulle à 35°C et elle est très affectée à 30°C pour tous les stades immatures. Nos résultats nous ont permis d'obtenir les valeurs des zéros de développement et des constantes thermiques pour les différents stades de cette espèce.

La biologie de *C. catioirii* n'avait encore jamais été étudiée. On constate que la survie de cette espèce est globalement moins bonne que celle des deux autres espèces étudiées. Cependant aucun milieu d'élevage n'a été réalisé spécialement pour *C. catioirii* : nous avons utilisé celui de *C. rosa*. On pourrait penser que le milieu est responsable d'une moins bonne survie des larves. D'un autre côté, pour certaines températures, la survie de *C. catioirii* est meilleure que celle de *C. rosa*. Il serait intéressant de vérifier les résultats obtenus sur *C. catioirii* avec d'autres milieux artificiels ou des fruits-hôtes.

Pour les trois espèces, les régressions linéaires réalisées entre température et taux de développement montrent des coefficients de corrélation très élevés pour la plupart. Le modèle des sommes de température semble donc bien approprié pour rendre compte du développement des espèces étudiées, entre 15 et 30°C.

Les seuils maxima létaux n'ont pu être définis avec précision, et il serait intéressant d'étudier plus en détail le développement pour des températures comprises entre 30 et 35°C. Nous avons également remarqué que l'étendue du temps de développement des stades immatures varie avec la température et ne dépend pas toujours exclusivement du temps de développement.

La comparaison des temps de développement entre les différentes espèces montre que celles-ci diffèrent surtout au niveau du stade larvaire.

**Conditions d'élevage**

Les insectes que nous avons utilisés proviennent d'un élevage et peuvent de ce fait, se comporter différemment d'insectes sauvages. Si les adultes sont élevés à température ambiante, les œufs, les larves et les pupes sont élevés à la température constante de 25°C. On pourrait craindre que les mouches d'élevage aient ainsi été sélectionnées pour cette température. Un moyen d'atténuer ce phénomène est d'introduire des mouches "sauvages" dans la cage d'élevage mais ceci ne fonctionne pas toujours, les croisements entre les deux souches se faisant difficilement. Par ailleurs, une étude menée sur *C. capitata* a montré qu'il n'y avait pas de différence significative entre les temps de développement larvaire d'une population élevée au laboratoire et une population "collectée au champ" (Muniz, 1987). Il serait intéressant de réaliser ce type d'étude sur les autres stades de développement pré-imaginaux et de comparer également la survie des deux types de populations. On pourrait en outre comparer la durée de développement larvaire sur fruits-hôtes et sur milieu artificiel. Il serait enfin intéressant de réaliser des essais avec températures fluctuantes, se rapprochant davantage des conditions naturelles.

**Répartition géographique**

Les taux de survie élevés de *C. capitata* dans une large gamme de température (15-30°C) peuvent expliquer sa large répartition géographique sur une grande partie de la planète et sous divers climats (White & Elson-Harris, 1992). Cependant, *C. capitata* étant peu ou pas présente dans les zones pluvieuses alors que la température lui semble favorable, il convient donc également de prendre en compte l'humidité comme facteur influençant sa répartition. *C. capitata* est une mouche adaptée au
climat de type méditerranéen plutôt que tropical, ce qui explique qu'elle souffre d'une forte compétition avec *C. rosa* dans les zones humides de l'île.

En ce qui concerne la répartition de *C. rosa* à La Réunion, on comprend mieux qu'elle soit présente en altitude car elle possède des seuils minimums de température plus faibles que ceux de *C. capitata*, notamment pour le stade larvaire où la différence est très importante. La moindre survie de *C. catoirii* dans la gamme de température étudiée pourrait expliquer qu'elle ait tendance à être dominée par les deux autres espèces dans la compétition interspécifique. Cependant, on a du mal à expliquer pourquoi elle est présente uniquement en zones de basse altitude là où les températures sont les plus élevées alors qu'elle possède des températures-seuils plutôt basses. La vitesse de développement larvaire et la survie des stades embryonnaire et larvaires étant supérieures à celles de *C. rosa* à 30°C, on aurait pu penser que, en zones de basse altitude, la compétition entre ces deux espèces soit en faveur de *C. catoirii*. Cependant, la température et la compétition interspécifique ne suffisent pas à expliquer pourquoi *C. catoirii* est surtout présente sur la côte Est de La Réunion. Celle-ci étant la partie la plus pluvieuse de l'île, on peut supposer qu'une humidité élevée constituerait le facteur plus favorable au développement de *C. catoirii* dans cette zone. Le moins grand nombre de fruits-hôtes de *C. catoirii* sur la côte Ouest pourrait également contribuer à expliquer la répartition de l'espèce.

**Implications pratiques**


Le présent travail devrait permettre d'améliorer l'élevage de *C. catoirii* dont les exigences thermiques étaient inconnues.

**REMERCIEMENTS**

Les auteurs remercient tout particulièrement Serge Glénac pour la conduite des élevages des 3 espèces de mouches.

**BIBLIOGRAPHIE**


Etude comparee de la biologie du developpement chez trois especes de mouches des fruits (ceratitis spp.) (diptera : tephritidae), nuisibles aux cultures fruitieres a la reunion. Pierre-François Duyck et Serge Quilici


113
HANDLING LARGE POPULATIONS OF SUGAR CANE GENOTYPES AT EARLY STAGES OF SELECTION IN MAURITIUS

D Santchurn, K Ramdoyal, L Rivet and H Mungur

Mauritius Sugar Industry Research Institute

ABSTRACT

Breeding in sugar cane involves the production of new populations of genotypes, which are subsequently screened and clonally multiplied through successive selection stages. This selection process spans over eleven to fifteen years in the MSIRI programme before a variety is released for commercial cultivation. The relative efficiency of plant breeding programmes worldwide depends on the breeders' ability to handle large populations at early generations, when individual genotypes are evaluated on small-unreplicated plots and planting material is limited. Optimum selection is achieved by selecting as weakly as possible in the beginning for highly heritable characters, intensifying selection only when substantial quantities of planting material of individual varieties are available to reduce environmental effects. With advances in computing hardware and software, it is now possible to reap maximum benefits from collected data with advantages ranging from small gains in selection efficiencies to new ways of sharing and applying research findings. The MSIRI has invested in the computerisation of selection data since 1960’s, which has improved the handling of data at all selection stages. The number of seedlings produced yearly for selection has increased to 100,000 and genotypes are now tested in several agro-climatic zones at an early stage. A redefinition of selection criteria and selection methods is desirable to address the new changes in the programme. This paper describes the methods of handling large populations and examines the efficiency of the selection parameters applied in early generation in the MSIRI programme.

Key words: computerisation, genotypes, Saccharum spp., selection criteria, and selection efficiency.

INTRODUCTION

New sugar cane varieties are produced by sexual means and propagated vegetatively. Each year a new population of original seedlings consisting of many thousands of new varieties is produced. These are screened clonally through several selection stages, their numbers being reduced at each stage and the selected ones tested in larger plots in which their performance can be evaluated more reliably. The time taken to release a sugar cane variety ranges from eight to twenty years (Skinner et al., 1987).

At early generations of selection since only limited plot sizes are allocated to large populations of genotypes of which few would be eventually released for commercial cultivation, there should be considerable savings from minimising effort on less useful material. Such savings can come from discriminating potential varieties from mediocre ones as early as possible in the selection process. Selection at early stages, however, is the least effective of all other stages due to unmanageably large populations making the process laborious and expensive, large competition effects and low broad-sense heritabilities of most characters. Bos (1983) showed that, in theory, with fixed resources, the expected genetic gain would be greater for a selection based on a broad screening of many genotypes rather than a more precise assessment of a smaller number. Simmonds (1979), as quoted by Skinner et al (1987) concluded that optimum selection is achieved by selecting as weakly as possible in the beginning and only for highly heritable characters, intensifying selection solely when substantial quantities of planting material of individual varieties are available to reduce environmental effects.

The relative efficiency of plant breeding programmes worldwide depends on the breeders’ ability to handle large populations at early generations. With advances in computing hardware and software, it is now possible to reap maximum value from collected information. The computerisation of breeding data at the Institute was initiated in 1966. Since then, there have been major advances in computer technology and the computer systems at MSIRI have kept up with these changes (MSIRI, 1995). Thus,
in 1995, the MSIRI adopted new technologies, making use of PCs connected to a local area network to enable sharing of data. As from 1988, relational databases were set up using Structured Query Language (Ramdoyal et al., 1999). Databases were developed to manage efficiently the large number of records and to enable navigation within and across databases easily. Furthermore, the adoption of data loggers in 1992 has enabled data capture in the field and downloading for rapid analysis, thus saving considerable time and avoiding errors.

In the 1980’s, several projects were initiated to assess the efficiency of the selection programme by analysing historical data and by setting up specific experimentation. In 1997 the selection system was strengthened following several series of past data analyses and, furthermore, through recommendations made by a team of reviewers (MSIRI, 1999). The major decisions taken were to:

a) Increase the population sizes in the preliminary phase,
b) Avoid bunch planting at the seedling stage,
c) Exploit as many environments as resources permit early in the selection programme, and
d) Select in plant cane in all unreleased trials.

Efficient handling of the large populations calls for simple and effective selection strategies and efficient use of available resources. This paper reviews the methods adopted at the MSIRI for handling large populations of genotypes in unreplicated trials. Historical data are further utilised to study the efficiency of selection parameters at these stages of selection.

The early stages of selection at the msiri

The selection programme in Mauritius is divided into six successive selection stages. The early stages comprise the seedling stage (stage 1), the first and the second clonal stages (stages 2 and 3 respectively) where genotypes are tested in unreplicated trials in the plant cane crop (Figure 1). Stage 1 involves 100,000 seedlings planted in cane rows of 1.5 m apart with the seedlings spaced at 60-75 cm. Stage 2 involves 15,000 to 25,000 genotypes planted in 2 m row plots. At stage 3, 2,500 to 3,500 genotypes are tested annually in single rows of 5 m in up to five environments. A late maturing commercial variety is planted in every sixth row for the purpose of comparison in both stages 2 and 3. Selected varieties from stage 3 are planted in replicated trials where more precise evaluations are made on cane and sucrose yields, ratooning ability, pest and disease reactions, and subsequently on ripening characteristics over several environments. Directed crosses and site specific selection for two extreme environments, very dry unirrigated (<1500 mm) and very humid (>2400 mm) areas started in 1987 (MSIRI, 1988). Some 10,000 seedlings have been produced annually for each environment. In the very humid zones, these are evaluated as from the seedling stage, whereas in the dry zone, due to climatic constraints, it was necessary to establish the seedlings in a humid environment first. Selected genotypes have then been evaluated in their respective agro climatic zones in 3 m plots thereby constituting the first clonal stage.

Evolution of genotype populations at early generations

In the 1950’s to late 1970’s, the number of seedlings produced annually ranged between 15,000 and 175,000. In years of overproduction, a maximum of 1000 seedlings per large family was retained for field-testing and the rest was destroyed. As from the mid 1970’s, due to improved methods of crossing, cleaning and storage of seeds, the production of some 60,000 seedlings was maintained. This population was increased to 80,000 by 1988 to cater for the two extreme agro climatic zones and up to 100,000 as from 1997 (Table 1).

The average number of genotypes evaluated at stage 2 in the 1990’s before 1997 was around 6000. This population has increased to 14,000 in year 2000 (Table 1). Until recently, genotypes at stage 2 were planted as single stools (a whole plant emanating from a hole). The plot size was increased to 2 m in 1998 to allow for a higher proportion of genotypes to be tested in a wider range of environments simultaneously as from the next selection stage.
Figure 1 The Selection programme

<table>
<thead>
<tr>
<th>Year planted</th>
<th>Month planted</th>
<th>Selection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 March</td>
<td>Single stool (unreplicated)</td>
<td>Visual selection</td>
</tr>
<tr>
<td>2 April</td>
<td>2 m rows (unreplicated)</td>
<td>Brix, vigour &amp; visual</td>
</tr>
<tr>
<td>3 July</td>
<td>5 m rows (unreplicated)</td>
<td>Weight, Brix, Kilo- Brix and visual</td>
</tr>
<tr>
<td>4 August</td>
<td>2 x 5 m rows (replicated)</td>
<td>Weight, Brix, Kilo- Brix and visual</td>
</tr>
<tr>
<td>7 March-May</td>
<td>4 x 10 m rows (replicated)</td>
<td>Weight, RSC@, disease resistance, profitability, adaptation, ratooning ability, Maturity trials</td>
</tr>
<tr>
<td>8 - 12 March-May</td>
<td>4 x 10 m rows (replicated)</td>
<td>-</td>
</tr>
<tr>
<td>11 - 15</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* : Target numbers
@: Industrially recoverable sugar percent cane

Table 1 Population size, number of genotypes evaluated and selection rates at unreplicated selection stages

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Seedlings produced</td>
<td>68 000</td>
<td>68 377</td>
<td>92 773</td>
<td>71 859</td>
<td>102 425</td>
<td>94 639</td>
<td>100 000</td>
<td>121 656</td>
<td>145 798</td>
<td>110 759</td>
</tr>
<tr>
<td>Locations planted</td>
<td>32 178</td>
<td>28 658</td>
<td>26 880</td>
<td>39 111</td>
<td>44 267</td>
<td>56 089</td>
<td>43 707</td>
<td>83 582</td>
<td>86 048</td>
<td>93 972</td>
</tr>
<tr>
<td>Selection %</td>
<td>9</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Stage 2</td>
<td>6 314</td>
<td>5 784</td>
<td>7 484</td>
<td>4 601</td>
<td>4 249</td>
<td>7 442</td>
<td>13 319</td>
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<tr>
<td>Selection %</td>
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<td>26</td>
<td>35</td>
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<td>Stage 3</td>
<td>2 177</td>
<td>2 258</td>
<td>2 708</td>
<td>2 040</td>
<td>1 182</td>
<td>1 495</td>
<td>1 597</td>
<td>1 610</td>
<td>1 902</td>
<td>1 748</td>
</tr>
</tbody>
</table>

At stage 3, on average some 2000 genotypes have been evaluated annually. Until late 1960’s, only vigorous genotypes (high number of cane stalks) were being tested systematically and simultaneously in the humid and super humid environments. Automation of data analysis allowed for less vigorous varieties hitherto not selected at stage 2, to be planted in the humid zone (Lalouette, 1968). As from the early 1980’s, highly vigorous varieties were tested in three locations concurrently, the sub humid, humid and super humid environments of the island. An analysis of selection rate at stage 2 indicated that of total clones selected, 60% (low vigour) were planted in one environment only, 38% (good vigour) in two and 2% (high vigour) in three environments simultaneously (Figure 2). Two more sites, representing the dry irrigated zone, have also been added in 1998 so that genotypes are tested in five agroclimatic regions of the island simultaneously as from stage 3 of selection (MSIRI, 1999).
Selection criteria and efficiencies

The seedling stage

Selection at the seedling stage is done by visual assessment on 13-14 months plant cane crops in April. No commercial controls are used and the selector retains clones based on a rapid visual judgement on a number of morphological characters. The selection of individual genotypes, planted in very small unreplicated plots, with high competitive effects is reported to be ineffective (Skinner 1972, Skinner et al. 1987, Wu and Tew 1989). Chang and Milligan (1992) also found that selection in seedlings results in approximately near-random selection for stalk number. Various selection studies with seedlings have found that stalk diameter is the most repeatable trait (Smith and James, 1969; Ladd et al., 1977; Ramdoyal, 1999). The objective at the MSIRI, therefore, has evolved towards rejecting only the worst genotypes at this stage based mainly on stalk diameter and some other secondary characters such as cracks, aerial roots, clinging leaf sheath, and excessive lodging.

The Institute, since early 1960’s, had adopted the Hawaiian system of bunching seedlings of large families during potting and transplantation in the field. For these families, bunches consisting each of three seedlings were planted in single locations and some 20 000 such plots were exploited in the past. In years before 1997, this number averaged to 40 000 for some 80 000 seedlings (Table 1). Competition between genotypes from the same location was high such that one genotype only could be selected from one location. Although this poor efficiency was reported in 1982 (MSIRI, 1983), it was not until 1997 that decisions were taken to plant seedlings singly.

Stage 2

Data have generally been collected in 15-16 months old crops, in the months of May and June. Brix has been the main selection criterion at this stage. With the automation of data processing in 1967, field Brix measured on the controls was analysed to estimate variability of the field within the trial and selection was based on the significance of the rows and columns components in the analysis of variance (Lalouette, 1968). In general, Brix of the control stools followed a normal distribution. Working in the upper tail area of the distribution, the overall rate of selection, usually at 10%, could be monitored beforehand. Visual appreciation was converted to a vigour code (TC), ranging from 0 to 3 for electronic analysis. The values represented the number of environments a genotype could be planted in one 5 m line plot at the next stage based on the number of cuttings available. An index was later constructed with the two selection parameters, Brix and vigour code. TC1 (low vigour) varieties were truncated at high Brix probability (P > 75%), TC2 (good vigour) at average probability (P > 50%) and TC3 (high vigour) varieties at low probability (P > 25%) with respect to the mean of controls (Figure 2).
3). In 1986, a five-point-scale breeders’ preference, graduating from 1 = excellent to 5 = reject, was added subsequently to represent the breeders’ visual judgement of genotypes at this stage. Selection of genotypes has then been based on three selection parameters, Brix, vigour code and visual grade. In the last decade, Brix probability has been adjusted at various levels to select about 2000 genotypes for the second clonal stage in relation to the availability of land.

**Figure 3** Distribution of Brix at stage 2 in 1997 (absolute values)

![Figure 3](image)

**Figure 4** Frequency of genotypes selected at stage 3 from vigour codes (TC) allocated at stage 2 in years 1990 to 1994.

![Figure 4](image)

The efficiencies of the above three selection parameters have been measured during selection at the next stage and are shown in **Figures 4, 5 and 6**. When vigour code was considered as the selection criterion at stage 2, a relatively higher proportion of vigorous clones (TC2 and TC3) were selected at stage 3 for inclusion in the first replicated trials (**Figure 4**). Except in 1993, visual grading indicated a similar tendency where a higher proportion of morphologically good genotypes (coded at stage 2) was selected for replicated trials (**Figure 5**). In years 1994 and 1995, when a uniform pressure of Brix probability (≥ 25%) across the grades was applied at stage 2, equal proportions of low, average and high probability Brix genotypes were promoted to stage 4 (**Figure 6**). Correlation of data between selection stages 2 and 3 showed that among the three selection parameters at the first clonal stage Brix was the most repeatable and consistent trait across years (**Table 2**).
Handling large populations of sugar cane genotypes at early stages of Selection in Mauritius Santchurn D et al.

**Table 2** Correlation of selection parameters between stages 2 and 3

<table>
<thead>
<tr>
<th>Selection Parameters</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vigour code</td>
<td>0.011</td>
<td>-0.001</td>
<td>0.284 **</td>
</tr>
<tr>
<td>Stalk number</td>
<td>0.041</td>
<td>0.139 **</td>
<td>0.253 **</td>
</tr>
<tr>
<td>Cane weight</td>
<td>0.210 **</td>
<td>0.183 **</td>
<td>0.182 **</td>
</tr>
<tr>
<td>Visual grade</td>
<td>0.315 **</td>
<td>0.435 **</td>
<td>0.259 **</td>
</tr>
<tr>
<td>Brix</td>
<td>2.257</td>
<td>2.707</td>
<td>2.039</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>2.257</td>
<td>2.707</td>
<td>2.039</td>
</tr>
</tbody>
</table>

**Stage 3**

At stage 3, the whole plot is weighed for the first time. Before 1967, selection at this stage consisted of a visual comparison of varieties with controls and an integration of Brix and weight in plant cane and first ratoon. The selection criterion that appeared most suitable for electronic data analysis was the product of cane weight and Brix for each plot and the term Kilo-Brix was coined for the first time (Lalouette, 1968). This value represents a crude estimate of sugar yield per unit area and has been used since then. Both cane weight and Kilo-Brix of the control populations follow a normal distribution and...
Handling large populations of sugar cane genotypes at early stages of Selection in Mauritius Santchurn D et al.

the selection zone had been defined as the upper tail area of the Kilo-Brix distribution at a probability of 75% or higher (Figure 7). Cane weight and Brix of controls have been utilised to adjust for spatial heterogeneity, as for the analysis of Brix at stage 2. A selection index was also adopted to promote average yielding varieties having high Brix probabilities. Visual appreciation of genotypes on a five-point scale, was extended to this population in 1986 (MSIRI, 1987). Selection in the last decade has mainly been based on the cumulative results of plant cane and first ratoon and using visual codes to promote morphologically best genotypes. Simulation studies in 1996 have shown that selection at this stage can be made with plant cane results only (MSIRI, 1997). This recommendation has been adopted to shorten the selection cycle by one year.

Figure 7 Distribution of Kilo-Brix in year 1993 (actual values)

Correlations of Brix and cane weight with Kilo-Brix at stage 3 for the last ten years (Table 3) indicated that Kilo-Brix was largely influenced by cane weight ($r = 0.96$ to $0.98$) and less so by Brix.

Table 3 Correlation coefficients among selection parameters at stage 3

<table>
<thead>
<tr>
<th>Selection parameters</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
<td>0.219 **</td>
</tr>
<tr>
<td>Kilo-Brix</td>
<td>0.974 **</td>
</tr>
<tr>
<td>Weight</td>
<td>2 257</td>
</tr>
</tbody>
</table>

Impact of large populations on resources at the MSIRI

The management of resources to ensure the smooth running of all selection operations is a key issue of the selection programme. Land and labour represent two main factors that are becoming highly expensive and require particular attention.

The estate land area exploited in unreplicated trials in the last ten years is shown in Table 4. Nearly 14 hectares of land were utilised annually until 1998. A drastic rise of 50% is observed due to the recent changes made in the selection programme. The land area at stage 1 has increased considerably as the result of population size (100 000) and planting of seedlings singly in the field. Increasing the plot size to 2 m and the number of genotypes at stage 2 has more than doubled the area under occupation at this stage. At stage 3, although the number of environments exploited has increased, the total area has
decreased by nearly 50% mainly because of the elimination of the first ratoon. The total estate land currently exploited in unreplicated trials amounts to 20 hectares annually.

**Table 4** Outfield land area (ha) exploited at early generation in the last ten years

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>4.48</td>
<td>4.53</td>
<td>4.03</td>
<td>3.78</td>
<td>4.40</td>
<td>4.98</td>
<td>6.31</td>
<td>4.92</td>
<td>9.40</td>
<td>9.62</td>
</tr>
<tr>
<td>Stage 2</td>
<td>1.94</td>
<td>1.83</td>
<td>1.73</td>
<td>2.22</td>
<td>1.54</td>
<td>1.85</td>
<td>1.78</td>
<td>3.10</td>
<td>4.20</td>
<td>6.63</td>
</tr>
<tr>
<td>Stage 3</td>
<td>4.86</td>
<td>5.81</td>
<td>6.85</td>
<td>8.56</td>
<td>9.36</td>
<td>7.43</td>
<td>6.52</td>
<td>6.21</td>
<td>7.62</td>
<td>3.31</td>
</tr>
</tbody>
</table>

The plant-breeding department has a labour force of about ten agricultural workers, which is supplemented by labour from MSIRI outstations and that obtainable from the sugar estates particularly during off-peak periods before the harvest season (**Figure 8**). With time, the different selection operations have been distributed in appropriate periods, within cropping constraints, so that manpower use is optimised. Before 1997, labour shortage was mostly felt from June to August reaching a peak in July. With the latest changes made in the selection system, acute labour shortage is observed from April to August and is solved by extra hours put by the support staff.

**DISCUSSION**

Efficient handling of large populations with limited resources implies timely and rapid execution of selection operations. Studies on past data at the MSIRI have been used to gauge the selection efficiency at early stages. At stage 1, since only the worst genotypes are rejected, visual selection appears to be the most convenient selection method. Selection at this stage and subsequent ones can be enhanced by an appropriate choice of parents (Ramdoyal et al. 1999) and cross evaluation techniques (Badaloo et al. 1999). Stage 2 represents a crucial phase where selection is based on estimated values. At stage 3, since absolute values are used, the risk of making wrong judgements is believed to be lower.

In order to improve sugar yield, the results obtained indicate cane tonnage is more important than Brix at the early stages of selection. High Brix probabilities at stage 2 do not seem to influence selection at stage 3. Instead, a higher proportion of vigorous and visually appreciable genotypes promoted to stage 3 would mean increasing the chances of getting higher yielding varieties in replicated trials. The relatively low correlation of Brix with Kilo-Brix (as compared to cane weight with Kilo-Brix) at stage 3 further support the hypothesis. However, the higher repeatability of Brix between selection stages means that it should be considered selection to ensure that Brix does not fall below a threshold level.

In the absence of cane weight, vigour code, mainly based on cane number, has been used for selection at stage 2. This parameter has given positive results. Various reports have shown that, in clonal crops, the most important component of yield is the number of millable stalks per unit area (Dosado et al., 1980; Nair et al., 1989). There is, however, a significant negative correlation between number of stalks per stool and stalk diameter and a compromise between these two traits has been proposed (James, 1971; Tai et al., 1980). Some attempts have been made to combine the different traits into a selection index. Miller et al. (1978) found it necessary to include cane number, cane diameter, cane length and Brix in the index to give satisfactory genetic advance. Selection index, however, has not been extensively adopted at early generations because the assessment of the important characters is time consuming and expensive. The adoption of visual grading that involves a rapid judgement on a set of agro-morphological characters, coupled with vigour at stage 2, therefore, has contributed towards higher selection efficiency.
To improve visual estimation and accurate data collection, timing of operations in selection is highly important. The best stage for sugar cane assessment has been identified as ten months old crops at the pre- and early harvest periods during which the phenotypic differences of various traits are high. Under the local context, Mamet (1999) observed that the relationship between field Brix and sucrose content was robust during April to July and tended to break down as from August/September. Ideally, early selection stages need to be implemented in July/August so that by April the following year the crops are at the right stage of evaluation. Figure 8 (broken lines) simulates the impact on manpower that this would entail and shows a peak in selection practices and labour requirements in the months of July and August. Alternative methods of transplanting seedlings without potting and mechanised weighing of plots offer some possibilities of adjusting the timing of operations towards higher efficiencies. Direct planting of seedlings in the field is practised in India and Reunion Island. Weighing equipment has enabled BSES (Australia) to handle larger populations at early stages, rely more on objective data and reduce the time to release new cultivars (Hogarth 1998).

Concurrently, an optimum use of land should be made to evaluate a large number of test genotypes at early stages. The amount of check plots used at stages 2 and 3 has undoubtedly enhanced local control and hence the genetic gain from selection. However, with the row and column design used at the Institute, the control variety occupies nearly 30% of the total area. New methods of controlling local heterogeneity in the field have been developed, such as spatial analysis where no commercial variety is used (Cullis et al., 1992) and augmented designs, where field variation for yield is adjusted in two dimensions (Federer and Raghavaraao, 1975; Lin and Poushinsky, 1983). The latter method of analysis is currently being tested under the local context where the number of check plots utilised can be decreased by nearly 50% (MSIRI, 1996). With the same land area currently exploited, some 2000 and 300 additional genotypes can be evaluated in the first and second clonal stages respectively, if results are conclusive.

CONCLUSION

The MSIRI sugar cane breeding programme has so far achieved great success in the production of sugar cane varieties that meet the various objectives of the industry. Among the recent modifications, plantating of genotypes singly at the seedling stage has evidently improved selection efficiency at this
stage. Increasing the plot size at stage 2 to exploit a greater number of environments as from an early stage will certainly lead to site specific higher yielding varieties. In this study, some of the major problems associated with handling of larger populations at the MSIRI and the means of achieving higher selection efficiency have been enumerated. Room for further improvement of managing early selection stages exists and must be addressed in the near future.

In general, plant breeding worldwide is experiencing major changes in technology and relative economics, the full strategic implications of which are not yet appreciated. But one point is clear: as the costs of generating field information continue to rise, the costs of managing that information are decreasing. Plant breeders must respond by ensuring that the data are collected efficiently using the best experimental practice and trial designs, and are fully utilised using modern methods for their management and analysis.

ACKNOWLEDGEMENTS

The authors wish to thank the Director, Dr L. Jean-Claude Autrey and the Deputy Director, Dr G. Claude Soopramanien of the MSIRI, for reviewing the paper.

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Handling large populations of sugar cane genotypes at early stages of Selection in Mauritius Santchurn D et al.


ELIMINATION OF SUGARCANE YELLOW LEAF VIRUS AND SUGARCANE BACILLIFORM VIRUS BY TISSUE CULTURE

Yogesh Parmessur and Asha Saumtally
Mauritius Sugar Industry Research Institute

ABSTRACT

The use of tissue culture was investigated as a means to eliminate sugarcane yellow leaf virus (ScYLV) – a luteovirus associated with sugarcane yellow leaf syndrome (YLS) and sugarcane bacilliform virus (SCBV). ScYLV was eliminated from two susceptible cultivars, M 695/69 and M 1658/78 as well as seven noble canes, Saccharum officinarum. Virus free plants were produced within six months using meristem tip, apical buds and embryogenic callus. Detection of the virus was carried out by RT-PCR using primer pairs YLS 111 and YLS 462. No virus could be detected in plants transferred to the glasshouse after they were checked at monthly intervals over a period of six months, thus confirming the elimination of ScYLV. The elimination of SCBV was also investigated by treatment with an antiviral agent, ribavirin. SCBV could not be eliminated from apical bud, meristem and micromeristem after ten subcultures on medium containing ribavirin at a concentration of 10-30 mg/l.

Keywords: tissue culture, virus elimination, sugarcane yellow leaf virus and sugarcane bacilliform virus.

INTRODUCTION

The elimination of plant viruses has been successfully achieved owing to their mode of replication and mechanism of movement within the plant. Three methods are currently in use, thermotherapy, tissue culture and chemotherapy. Although heat has been used for more than a century in the elimination of plant pathogens, it was not until 1949 that the first successful heat treatment of a virus infected plant was reported (Kassanis 1949). However, only during the late 1960’s, more than 70 viruses were reported to have been inactivated in plants by the use of heat treatment (Nyland and Gohen 1969). The effect of heat on viruses is not well understood but it is believed to be effective in inhibiting viral replication and synthesis of movement proteins mainly by blocking transcription (Mink et al 1998).

The most widely used method of virus elimination remains the technique known as meristem tip culture. This technique takes advantage of the fact that many viruses fail to invade the meristematic region. Transfer of the meristem dome together with one or two leaf primordia to a culture medium and its regeneration into a plantlet may lead to the elimination of a virus.

Antiviral agents have also been reported to be effective in the elimination of a number of viruses (Klein and Livingston 1983, Toussaint et al 1993). These compounds were initially designated for administration in humans and animals. However, because of their broad-spectrum activity, their use has been extended to plant viruses as well. They can be directly sprayed on the crop or included in tissue culture medium and upon uptake by the plant, they inhibit virus replication.

In Mauritius, sugarcane is infected by various viruses including sugarcane bacilliform virus (SCBV) and sugarcane yellow leaf virus (ScYLV). The latter is suspected to be the causal agent of the yellow leaf syndrome (YLS). SCBV was first reported as a sugarcane pathogen by Lockhart and Autrey in Morocco (1988). It was subsequently found to occur worldwide in almost all clones of noble canes, Saccharum officinarum and in several commercial cultivars. It is a member of the badnavirus group, the virus particles being bacilliform in shape (30 x 130 nm) and contains a double-stranded DNA genome. Ultrastructural studies (Peralta et al 1991) of infected leaf cells show that the virus is randomly distributed in the cytoplasm affecting the internal structure of the mitochondria, enhancing the quantity of plastids and inducing the formation of filamentous inclusions in the nucleus. Symptoms of naturally infected S. officinarum vary from no apparent foliar damage to pronounced whitish chlorotic streaking, the most common symptom being yellow or white freckles on sugarcane leaves.
Since the late 1980’s, sugarcane has demonstrated symptoms of a condition now known as the yellow leaf syndrome. It was eventually recognized as a sugarcane disease by Schenk (1990) in Hawaii. A luteovirus, ScYLV, found to reside in the phloem of diseased canes has been associated with the syndrome (Schenk et al 1997). It has been classified as a luteoviridae with properties of both subgroups of I and II of luteoviruses (Moonan et al 1999). The symptoms of YLS appear in maturing plants generally starting as a yellowing of the leaf midribs and are most easily seen on the abaxial surface. Sometimes, a pinkish red discoloration on the upper surface of the midribs is also present. Thereafter a symmetrical discoloration of the leaf lamina parallel to the midrib can become evident and as the season progresses, the entire lamina and most of the canopy turns yellow. Losses as high as 40-60% have been reported in Brazil (Comstock et al 1994, Lockhart et al 1996).

A virus cleaning programme was therefore set up in order to eliminate both SCBV and ScYLV from noble canes and commercial varieties by in vitro techniques. This would provide us with virus free material in order to carry out yield loss and transmission studies, to maintain the existing germplasm, virus-free and to avoid the introduction of new strains from imported varieties. Two strategies were adopted; (1) conventional tissue culture and (2) the treatment of in vitro plants with the antiviral agent ribavirin.

MATERIALS AND METHODS

The experiment was carried out in two parts. Firstly, twenty plants from two commercial varieties (M 1658/78 and M 695/69) and nine noble cane varieties were used for the elimination of ScYLV by tissue culture. Secondly, ten varieties of noble cane established in vitro (four varieties infected with SCBV only and six varieties infected with both SCBV and ScYLV) were used for treatment with ribavirin.

In vitro culture of canes for the elimination of ScYLV

Twenty cane tops, each from varieties M 1658/78 and M 695/69 infected with ScYLV were used for tissue culture. Young leaf rolls about 5 mm thick were cultured in the dark on callus induction medium (MS salts, Gamborg’s B5 vitamins, 3.0 mg l-1 2,4-D, 6.7 g l-1 glucose, 13.3 g l-1 sucrose and 1.8 g l-1 phytagel). Embryogenic callus was subcultured at monthly intervals and was regenerated on a medium devoid of 2,4-D. To determine the minimum number of callus culture required for the elimination of the virus, plantlets were regenerated at each subculture. Axillary buds and apical meristem were also used as explants and regenerated into plantlets using a modified MS medium (Gopee 1994). Similarly, nine noble canes varieties were also cultured in vitro.

Total nucleic acids extraction

Total nucleic acids were extracted from the leaves by using the hot CTAB method: In vitro plant tissue (0.3 g) was ground in liquid nitrogen using a mortar and pestle. The finely ground powder was transferred into an Eppendorf tube containing 1 ml extraction buffer (EDTA; 20 mM pH 8.0, NaCl; 1.4 M, CTAB; 2% and 0.2% β Mercaptoethanol) and incubated at 60°C for 30 min. The extract was then mixed with 2/3 (v/v) chloroform : isoamyl alcohol (24:1) and centrifuged at 12 000 rpm. The supernatant (0.75 ml) was transferred into a new tube, gently mixed with 2/3 (v/v) cold isopropanol. Total nucleic acids were precipitated upon incubation at -20°C for 1h. Nucleic acids were pelleted by spinning at 10,000 rpm for 5 min then, washed with ethanol (76%) and sodium acetate (10 mM). The pellet was dried and dissolved in sterile distilled water (20 µl).

Total nucleic acids were also extracted from the first fully unrolled leaf of grown up plants using the CTAB method.

PCR conditions

Primers YLS 462 and YLS 111 (primers sequences were provided by Dr M Irey, US Sugar Corporation, Florida, USA) which amplify part of the gene encoding the coat protein of ScYLV was used for the detection of the virus (Comstock et al 1998). RT-PCR was carried out in a thermal cycler (PTC 100 MJ Research). Crude samples (0.50 µl) were boiled with 0.25 µl primer YLS 462 (30 µM) for 5 min and quenched on ice. The samples were then mixed with aliquots (4.25 µl) of the following
Elimination of sugarcane yellow leaf virus and sugarcane bacilliform virus by tissue culture. Y Parmessur and A Saumtally.


In vitro assay of ribavirin

The phytotoxic effect of ribavirin was tested on plantlets of four varieties of noble canes (D 1135, M 13/18, M 168/33 and MB 09/72). For each variety, a single shoot was transferred in tissue culture medium (TCM) containing ribavirin (10-75 mg/l). After one month, the number of adventitious shoots arising per mother plant was counted. This was considered as a measure of phytotoxicity. A single shoot from each assay was taken and was further subcultured for one month on medium containing the same concentration of ribavirin. Again, the number of plantlets arising from each mother plant was counted.

To determine the effect of light on the activity of ribavirin, TCM containing ribavirin (10-75 mg/l) was exposed to light for 2 months. A control with the above medium maintained in the dark was also included in the experiment. Single shoots (variety M 168/33) were then transferred into each jar. After one month, the number of adventitious shoots arising per plant was noted.

In vitro treatment of noble canes

Plantlets infected with either SCBV or both SCBV and ScYLV (Table 1) were treated in vitro with ribavirin in an attempt to eliminate the viruses. Single shoots from each variety were transferred to TCM containing ribavirin at the following concentrations: 10, 15, 20, 25 and 30 mg/l. When adventitious shoots reached 4-5 cm in height, a single shoot was separated from the mother plant and transferred to fresh TCM containing the same concentration of ribavirin. The hot CTAB method was used for total nucleic acid extraction. The plantlets were randomly tested for SCBV and ScYLV by PCR and RT-PCR respectively for the next 7-10 subcultures. Micromeristem tips from plantlets of variety M 168/33, treated with ribavirin at concentrations between 10-25 mg/l were dissected and further cultured in vitro. Upon regeneration, plantlets were tested for SCBV by PCR.
Elimination of sugarcane yellow leaf virus and sugarcane bacilliform virus by tissue culture. Y Parmessur and A Saumtally.

Table 1 Noble canes infected with SCBV and ScYLV treated with ribavirin at 10-30 mg/l

<table>
<thead>
<tr>
<th>Variety</th>
<th>Origin of plantlet treated in vitro with ribavirin</th>
<th>Viruses detected in plantlet prior to ribavirin treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 5913</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV -</td>
</tr>
<tr>
<td>D 1135</td>
<td>Meristem tip</td>
<td>SCBV + ScYLV -</td>
</tr>
<tr>
<td>DI 0052</td>
<td>Meristem tip</td>
<td>SCBV + ScYLV -</td>
</tr>
<tr>
<td>M 13/18</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>M 27/16</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>M 29/16</td>
<td>Meristem tip</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>M 35/17</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>M 168/33</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>M 1182/55</td>
<td>Axillary bud</td>
<td>SCBV + ScYLV +</td>
</tr>
<tr>
<td>MB 09/72</td>
<td>Meristem tip</td>
<td>SCBV + ScYLV -</td>
</tr>
</tbody>
</table>

RESULTS

In the commercial varieties, ScYLV was eliminated from 64% plantlets derived from apical meristem (Table 2). Furthermore, three out of 52 plantlets regenerated from axillary buds and all plants regenerated from callus subculture were found free from the virus. A single callus subculture was found to be sufficient for the elimination of ScYLV. The pathogen was also eliminated from seven varieties of noble canes using callus culture, (varieties M 68/33, M 168/33, MB 009/72 and M 27/16), bud culture (varieties M 68/33, M 168/33, and MB 09/72) and meristem tip culture (varieties M 13/18, M 168/33, M 171/18 and M 1182/55).

Table 2 Elimination of ScYLV from commercial canes by meristem tip culture

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plantlets regenerated</th>
<th>ScYLV +ve</th>
<th>ScYLV -ve</th>
<th>% elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 695/69</td>
<td>6/20</td>
<td>2</td>
<td>4</td>
<td>67</td>
</tr>
<tr>
<td>M 1658/78</td>
<td>8/20</td>
<td>2</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>4</td>
<td>10</td>
<td>64</td>
</tr>
</tbody>
</table>

Plantlets of variety M 168/33 derived from callus, meristem tip and axillary bud were grown in the glasshouse and tested for ScYLV by RT-PCR at monthly intervals. The pathogen remained undetected from the plants six months after being sent to the glasshouse, confirming its absence.

Figure 1 shows the effect of ribavirin on the in vitro multiplication of noble canes. Increasing ribavirin concentration causes a fall in the multiplication rate of noble canes irrespective of the variety tested. At a concentration of 60 mg/l or above multiplication of noble canes in vitro almost ceased. Upon subculture, a similar trend in multiplication rate was observed at ribavirin concentration 10-30 mg/l. Moreover, plantlets exposed to higher ribavirin concentrations turned yellow and eventually died. A decrease in the rate of growth of the plant (height) was also noted with increasing ribavirin concentration. Exposure to light appeared to have no effect on the activity of ribavirin. Plantlets treated with ribavirin at a concentration of 30 mg/l perished after three subcultures. At lower concentrations, all plantlets tested for SCBV and ScYLV by PCR and RT-PCR respectively remained infected with the pathogens. After 7-10 subcultures, plantlets of variety M 168/33, regenerated from micromeristem tip also remained infected with SCBV when tested by PCR.
**DISCUSSION**

In this experimental work, it has been possible to eliminate ScYLV from the noble canes and commercial varieties by using meristem tip, axillary bud and callus culture. Meristem tip culture is the most common method of virus elimination in plants. This technique takes advantage of the fact that some viruses are unable to colonise this region because of inhibition of replication and restriction of their movement (Faccioli and Morani 1998). Two factors could impede with the replication of ScYLV at the meristem tip; a high concentration of auxin and depletion of nutrients through rapid cell division and secondly the inability of the luteovirus to reside in the meristem as a result of:

a) localisation of the virus in the phloem which is not differentiated yet at the meristem tip  
b) inability of the virus to move vertically across the plant through the plasmodesmata to the meristem tip and  
c) inability of the virus to keep up with the pace of rapidly dividing cells at the growing point.

It was also possible to eliminate the virus from infected plants by the culture of callus derived from leaf rolls. The uneven distribution of the virus among the different tissues of the leaf may account for its elimination. ScYLV has been found to be phloem-restricted whereas somatic embryos have been found to arise mainly from non-vascular tissue (Guideroni and Demarli 1988). Therefore plantlets derived from callus culture are likely to be derived from virus free cells, hence should in turn be free from ScYLV. Secondly, a high concentration of auxin in TCM may also inhibit viral replication.

*In vitro* culture has been found to be an easy method for the elimination of ScYLV from infected plants. Plantlets free from ScYLV can be produced within six months from meristem tip, axillary bud and callus. The success of meristem tip culture resides in the ability to dissect the meristematic dome with one or two leaf primordia from the mother plant and its successful regeneration. Large meristem tips (>1mm) are likely to be infected whereas smaller ones (<0.3mm) are unlikely to regenerate. Cleaning through callus subculture requires less skill and all plants regenerated are virus free. However, callus culture of sugarcane should be treated cautiously due to possible somaclonal variation.

Sugarcane bacilliform virus has been detected in the axillary buds and axillary meristematic domes and plantlets derived from buds and domes (Braithwaite et al 1994). Due to its systemic distribution, *in vitro* culture of infected canes has not been successful in eliminating the virus. The use of heat on both cane setts and axillary buds have also failed to eliminate the virus (Braithwaite et al 1994). In this experiment, attempts were made to eliminate SCBV and ScYLV from infected plants by treatment with

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**Figure 1** Changes in the multiplication rate of noble canes (varieties D 1135, M 13 / 18, M 168 / 33 and MB 09 / 72) after 1 month exposure to TCM containing ribavirin.
the antiviral agent ribavirin. This compound exerts its effect on both DNA and RNA viruses and has been used in the elimination of a number of plant viruses, including Potato virus X, Potato virus Y (Klein and Livingston 1983) at 10 mg/l and Odontoglossum ringspot virus (Toussaint et al 1993) at 35 mg/l. However, in our experiments, ribavirin failed to eliminate SCBV and ScYLV when used at 10-30 mg/l.

One of the proposed modes of activity of ribavirin is that it causes a fall in the intracellular level of guanosine triphosphate and deoxyguanosine triphosphate (De Clerk 1991). At such low concentrations, replication of the virus is hindered, hence after a number of subcultures, elimination of the virus is possible through serial dilution. This concentration however needs to be below the concentration at which it is phytotoxic to the plant. Therefore the inability of ribavirin to eliminate SCBV and ScYLV is probably because its antiviral concentration is higher than 30 mg/l and this level is phytotoxic to sugarcane.

ACKNOWLEDGEMENTS

We would like to thank Dr J.C. Autrey, Director and Dr C. Soopramanien, Deputy Director, MSIRI, for their continuous support throughout this work and the Mauritius Research Council for partly funding this project.

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Oxadiargyl, a new pre-emergence herbicide, has been evaluated in potato for its ecotoxicological characteristics and for broader spectrum weed control as objectives. The new product has been tested in potato grown in full-stand and in interrows of sugar cane at rates varying between 0.25 and 0.5 kg a.i. ha$^{-1}$. The control obtained with oxadiargyl at rates above 0.30 kg a.i. ha$^{-1}$ was comparable to that of the standard metribuzin at 1.0 kg a.i. ha$^{-1}$; the new herbicide was superior to the standard on Solanum nigrum, a weed of common occurrence in potato plantations, and Panicum subalbidum. Growth and yield of potato were unaffected by oxadiargyl irrespective of rate. Oxadiargyl has been recommended as an alternative herbicide to metribuzin at rates varying between 0.35 to 0.4 kg a.i. ha$^{-1}$.

Keywords: oxadiargyl, potato, weed control, pre-emergence, Solanum nigrum, Panicum subalbidum

**INTRODUCTION**

In Mauritius, potato is grown either in full stand or in cane interrows. The average annual production is about 17 000 tonnes and in 1999 15 000 tonnes were harvested on an area of 640 hectares (Central Statistical office, 2000). Since the introduction of this crop and until the early 1970's, manual weeding was the only method of weed control and was carried out simultaneously during earthing-up operations. However, this method of control is labour intensive and costly and has a significant bearing on the cost of production of that commodity.

In 1974, the Mauritius Sugar Industry Research Institute (MSIRI) initiated trials with the object of determining whether chemical weed control in potato plantations could be resorted to. This led to the recommendation of two pre-emergence herbicides, namely, linuron and metribuzin (Mc Intyre, 1975), and a third one, Topogard (MSIRI, 1982). The three herbicides proved safe to potato and sugar cane and have been found to provide reasonable control of annual grasses and broad-leaved weeds.

During the last decade, emphasis has been laid on the screening of more efficient and safer herbicides for sugar cane and associated crops. The new herbicide oxadiargyl (Raft®) has thus been evaluated in potato for its ecotoxicological characteristics (Anon, 1997) and for broader spectrum weed control as objectives.

Oxadiargyl is a pre-emergence herbicide effective on grasses, broad-leaved weeds and annual sedges. The product has been developed primarily for general weed control in rice and sugar cane (Dickmann et al., 1997). At 0.3 to 0.4 kg a.i. ha$^{-1}$ it was well tolerated by sunflower and transplanted vegetables like tomato and cabbage when applied pre-emergence or pre-transplanting (Tracchi et al., 1997). My (1997) suggests that the product may have some potential in potato. However, no work has been reported so far on the use of oxadiargyl in potato plantations.

This paper reports on results of trials carried out to evaluate the efficacy of oxadiargyl for general weed control in potato established in full stand and in cane interrows.

**MATERIALS AND METHODS**

Four field trials, two in cane interrows at Bel Air (Trials I and IV) and two in full stand at Réduit (Trial II) and Labourdonnais (Trial III), have been conducted in 1999 to evaluate oxadiargyl (trade name Raft®). The control obtained with oxadiargyl at rates above 0.30 kg a.i. ha$^{-1}$ was comparable to that of the standard metribuzin at 1.0 kg a.i. ha$^{-1}$; the new herbicide was superior to the standard on Solanum nigrum, a weed of common occurrence in potato plantations, and Panicum subalbidum. Growth and yield of potato were unaffected by oxadiargyl irrespective of rate. Oxadiargyl has been recommended as an alternative herbicide to metribuzin at rates varying between 0.35 to 0.4 kg a.i. ha$^{-1}$.

**Keywords:** oxadiargyl, potato, weed control, pre-emergence, Solanum nigrum, Panicum subalbidum
Oxadiargyl: a new pre-emergence herbicide recommended in potato in Mauritius

C. Barbe et al.


136

Raft) for general weed control in potato. Characteristics and details of experimental sites are given in Table 1.

**Table 1** Characteristics and details of experimental sites

<table>
<thead>
<tr>
<th>Trial</th>
<th>Site</th>
<th>Soil Group*</th>
<th>Altitude m</th>
<th>Annual Rainfall mm</th>
<th>Potato variety</th>
<th>Date of spraying</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Bel Air</td>
<td>L2</td>
<td>150</td>
<td>2 075</td>
<td>Mondial</td>
<td>27-Apr-99</td>
</tr>
<tr>
<td>II</td>
<td>Réduit</td>
<td>L2</td>
<td>305</td>
<td>1 500</td>
<td>Spunta</td>
<td>14-May-99</td>
</tr>
<tr>
<td>III</td>
<td>Labourdonnais</td>
<td>P2</td>
<td>90</td>
<td>1 500</td>
<td></td>
<td>18-May-99</td>
</tr>
<tr>
<td>IV</td>
<td>Bel Air</td>
<td>L2</td>
<td>75</td>
<td>1 725</td>
<td></td>
<td>17-Aug-99</td>
</tr>
</tbody>
</table>

*Source: Parish and Feillafé (1965)*

In all trials, oxadiargyl @ 0.25, 0.30, 0.35, 0.40, 0.45 and 0.50 kg a.i. ha\(^{-1}\) were compared to metribuzin @ 1.0 kg a.i. ha\(^{-1}\) as standard and to an untreated control. Spraying was done in pre-emergence of weeds, potato and cane with the use of hand-operated knapsack sprayers, delivering 640 litres spray mixture at a working pressure of 300 kPa.

The statistical design was a completely randomized block with four replicates; plot size at Bel Air (Trials I and IV) was 64 m\(^2\), consisting of four potato rows and five cane rows 10 m long at a spacing of 1.6 m. At Réduit (Trial II) and Labourdonnais (Trial III), where trials were established in full stand, plot size was 48 m\(^2\) with six potato rows spaced at 0.8 m.

Observations were made at regular intervals and final weed surveys carried out between five and eight weeks after spraying using the frequency abundance method (Rochecouste, 1967). Potato yield in the various treatments was determined by weighing the two middle rows at Bel Air (Trial IV) and four middle rows at Réduit and Labourdonnais (Trials II and III).

**RESULTS AND DISCUSSION**

**Weed Control**

At Réduit (Trial II) and Labourdonnais (Trial III) weed population was so low, that the efficiency of the various treatments could not be determined.

The main weed species present in the untreated control in Trial I were *Ageratum conyzoides, Amaranthus viridis, Elesine indica, Oxalis corniculata, Panicum subalbidum, Phyllanthus* spp and *Solanum nigrum*. Observations made four weeks after spraying showed a good level of control of weeds with the lowest rate of oxadiargyl, control improving with increasing dosage. This was confirmed four weeks later when oxadiargyl @ 0.3 and 0.35 kg a.i. ha\(^{-1}\) was comparable to the standard metribuzin and superior to the latter as from 0.4 kg a.i. ha\(^{-1}\) (*Table 2*). Besides, oxadiargyl was more effective than metribuzin on *Panicum subalbidum*, a problem weed in many sugar cane fields and *Solanum nigrum* which is of common occurrence in potato plantations because of the weaknesses of metribuzin on solanaceous weeds. This efficacy of oxadiargyl on *S. nigrum* has also been reported by Tracchi *et al* (1997).

In trial IV at Bel Air where the main weed species comprised *Oxalis corniculata, Panicum subalbidum, Phyllanthus* spp and *Panicum maximum*, the level of control obtained with the different rates of oxadiargyl followed the same trend with that observed in Trial I (*Table 2*). The superiority of oxadiargyl over metribuzin on *Panicum subalbidum* was again observed in this trial.

**Effect on potato growth and yield**

At all trial sites slight scorching on the lower leaves was observed in the first three weeks after spraying with the three higher rates of oxadiargyl. However this effect did not progress and all new leaves emerged unaffected.
Table 2 Pre-emergence weed control with oxadiargyl

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dosage kg a.i. ha⁻¹</th>
<th>Weed Abundance % of untreated control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trial I 5 WAS*</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.25</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>14</td>
</tr>
<tr>
<td>Metribuzin (Standard)</td>
<td>1.00</td>
<td>22</td>
</tr>
</tbody>
</table>

* WAS = Weeks after spraying

Harvest results of trials II, III and IV showed that oxadiargyl, irrespective of rate, was well tolerated by potato variety Spunta (Table 3). Trial I was accidentally harvested so that yields could not be determined. However visual observations made over a ten-week period did not reveal any phytotoxicity of oxadiargyl on variety Mondial.

Table 3 Effect of oxadiargyl on commercial yield of potato variety Spunta tha⁻¹

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dosage kg a.i. ha⁻¹</th>
<th>Trial II Réduit</th>
<th>Trial III Labourdonnais</th>
<th>Trial IV Bel Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxadiargyl</td>
<td>0.25</td>
<td>21.6</td>
<td>16.6</td>
<td>10.4</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.30</td>
<td>23.9</td>
<td>15.8</td>
<td>10.1</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.35</td>
<td>23.5</td>
<td>16.8</td>
<td>10.9</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.40</td>
<td>20.7</td>
<td>17.9</td>
<td>9.4</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.45</td>
<td>22.2</td>
<td>16.7</td>
<td>9.0</td>
</tr>
<tr>
<td>Oxadiargyl</td>
<td>0.50</td>
<td>22.3</td>
<td>17.9</td>
<td>8.8</td>
</tr>
<tr>
<td>Metribuzin (Standard)</td>
<td>1.00</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Lsd 0.05</td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

CONCLUSION

Trials have shown that oxadiargyl provides good control of both grasses and broad-leaved weeds. The control obtained with oxadiargyl between 0.3 and 0.4 kg a.i. ha⁻¹ was comparable to the standard metribuzin and superior to the latter @ 0.4 kg a.i. ha⁻¹ and above. The product proved more effective on P. subalbidum and S. nigrum. Growth and yield of potato were unaffected irrespective of rate applied. Oxadiargyl having good ecotoxicological properties is a good alternative to metribuzin and has been recommended for use at commercial level at rates varying between 0.35 and 0.4 kg a.i. ha⁻¹.

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The authors would like to thank the Agronomists of sugar estates involved for facilities granted in the establishment of the trials. Grateful thanks are also due to the Director, M.S.I.R.I, for reviewing this paper.
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EFFECT OF LIME ON NUTRIENT CONTENT OF SOILS, YIELD AND NUTRIENT CONTENT OF POTATO AND INFECTION BY LEAFMINERS

B Lalljee and S Facknath

Faculty of Agriculture, University of Mauritius

ABSTRACT

The effects of lime application on micronutrient content of soil and yield and nutrient of two varieties of potato, Solanum tuberosum, were studied. Lime addition at various rates, 0, 4, 8 and 12 t ha\(^{-1}\) increased pH of soil from 5.12 to 7.22 in a period of 12 weeks. Available soil zinc, copper, iron and manganese decreased with increasing levels of lime, whereas available boron increased. Liming had positive effects on the yield, protein content, ash, starch, and calcium of both varieties of potato tubers. However, Zn, Cu, Fe and P decreased with increased application of lime. All results were significant at 5% level. Leaf miner infestation was not significant in terms of numbers of adults, but showed a slight significance with respect to punctures on treated leaves.

Key words: lime, potato varieties, zinc, copper, iron, manganese, boron, yield, protein content, ash, starch, Ca, Zn, Cu, Fe, P, leaf miner infestation.

INTRODUCTION

Most of the soils of Mauritius are mature, Latosols and Latosolic soils. Base saturation of the Latosols is low and the pH is on the acidic side. Although liming is an age-old agricultural practice, it is not very popular in Mauritius; although recently some planters are using coral sand as a liming material. Cement has also been recommended to correct acidity in Mauritian soils (Ng Kee Kwong et al. 1993). Feillafe (1955) showed that the gravelly soils of Mauritius of the super-humid zone responded positively to 2t of lime per hectare. However, Ng Kee Kwong et al. (1980) did not observe any yield increase in sugarcane from soils not deficient in silicon. In fact, high doses of lime depressed yield. Liming is essential in highly leached acid soils for increasing soil fertility as it promotes a congenial chemical and biological environment (Sahaet.al 1999). High rate of nitrogen is necessary to achieve yield goals and to satisfy market commitments. Leaching of nitrate may be accelerated from the top soil and from the rooting zone, leading to acidification (Chan et al. 1999). However, the primary purpose of liming is to neutralise exchangeable Al, and this is normally attained by raising the pH of the soil to 5.5. According to Kanprath (1971), lime requirement can be roughly calculated by multiplying the exchangeable Al in milli-equivalent by 1.5. The result is milli-equivalent of Ca to be applied as lime. Over-liming of leached tropical soils may lead to yield reduction, soil structure deterioration and decreased availability of phosphorus, B, Zn and Mn (Sanchez 1976). Over-liming soils which are high in oxide coatings increases the absorption of B by clays and reduces the availability of B (Kanprath 1971). Solubility of Zn decreases rapidly at pH 6 or 7. The bulk of the evidence suggests that highly weathered soil should not be limed to pH greater than 5.5 as yield decreases can occur (Sanchez 1976). Lime stimulates the general heterotrophs by regulating microbial activity. pH affects mineralisation of organic matter and subsequent availability of major and minor nutrients. Fageria et al. (1991, 1995) reported that increasing levels of lime tended to reduce uptake of P, Zn, Cu, Mn and Fe, and increased uptake of Ca and Mg in rice, wheat, common bean and maize. Liming significantly increased dry weight of crops of all the species tested as well as dry weights of roots of wheat and maize, but had significant negative effects on rice growth. Ambak et al. (1991) reported no difference in yield of maize and tomato from soil treated with lime above 8 t ha\(^{-1}\). When micronutrients were not applied, shoot growth of maize was enhanced with increase of lime upto 8 t/ha only. Potato (Solanum tuberosum) has been shown to respond to lime addition on acid soils (Anon 2001). Liming is suggested when the pH is less than 5 and soil tests for calcium is less than 4 m.e. %.
Potato crops respond well to optimum fertiliser level, in terms of both yield and quality. Excessive fertiliser application delays tuber set and maturity. Delayed maturity can lead to reduced starch and elevated sugar levels at harvest, which make the tubers unsuitable for processing.

The objectives of this experiment were to observe any change, positive or negative, in trace element concentration of soil as well as concentration of nutrients and yield of potato tubers grown in lime-amended soil. Potato was chosen as a test crop because there is a potential to increase its production. Potato is also grown as an interline crop, and soil amendment for sugarcane will undoubtedly affect yield and quality of potato.

MATERIALS AND METHODS

Local lime, available in hardware shops, was powdered and sieved to pass through a 100 mesh sieve. This was used for the experiments. Different amounts of this lime were broadcast on the experimental plots so as to produce rates of 0 t ha\(^{-1}\), 4 t ha\(^{-1}\), 8 t ha\(^{-1}\), 12 t ha\(^{-1}\), 4 x 4 factorial design with 4 rates of lime and 4 periods of observation for soil, replicated 4 times. The lime was incorporated in the 0-20 cm layer of soil, 15 days prior to sowing of the potato seeds.

Soil analyses were performed as per the method of Sillaanpa (1990). Acid-EDTA was used as an extractant for Cu, Zn, Fe and Mn, and the estimations were made on a solar 929 Atomic Absorption Spectrophotometer. B was determined colorimetrically by the azomethine-H method (Sippola and Ervio 1977).

Two varieties of potato, namely Delaware and Up-to-Date were planted in the untreated (control) and the lime-amended plots. Clean seeds, obtained from the Agricultural Marketing Board, were conditioned for 3 days prior to sowing. Cultural practices were followed as per recommended methods (Anon 1998).

The following analyses were done on the harvested potato tubers: tuber yield (fresh weight), protein, ash, starch, calcium, phosphorus, zinc, iron, copper, as per standard methods (Paul and Southgate 1985). All results shown are on a dry matter basis.

Response of the leafminer (Liriomyza spp.) adults to leaves taken from potato plants from the different plots was studied in laboratory cages, in terms of adult preference as well as number of feeding and oviposition punctures.

RESULTS AND DISCUSSION

The results of the experiments are shown in Figures 1 and 2 and Tables 1 to 11. Figure 1 gives the profiles of available Zn, Cu and B with time. The availability of Zn decreased, both with increasing rates of lime applied as well as with time. For the 12 t ha\(^{-1}\) at 12 weeks, the decrease was 35%, whereas in the 0 - 4 week period, the decrease was only 7.2%. All the differences, whether for rate of lime application or reaction time, were significant at the 5% level.

For available Cu, there was an initial bigger decrease compared to Zn, followed by a plateau and then an increase (Figure 1). Overall, however there was a reduction in Cu at the end of 12 weeks. At 12 weeks, the 12 t ha\(^{-1}\) treatment gave a reduction in available Cu of 24.5%, representing a decrease of 4.5 kg ha\(^{-1}\) of available Cu. Overall, there were significant differences at the 5% level, for both rate of lime as well as time. Interactions were not significant.

The case for available B was different from Zn or Cu. With time, the rate of lime had a significant effect on B (Figure 1). The largest change in available B occurred for the 12 t treatment after 8 weeks, following which there was a slight reduction. At 8 weeks, the 12 t ha\(^{-1}\) treatment represented an increase of 34.4% in available B.

Significant reductions in Fe and Mn were noted (Figure 2). There was a drastic reduction in week 4, followed by a gradual reduction thereafter. For the various rates of lime, the following reductions were noted during the 4th week: 9.3%, 20.8% and 35.1% respectively for the 4t, 8t and 12t treatments. Reduction in available Mn was more uniform, with maximum reduction occurring at week 12 (21%, 36.1%, and 40.8% for the 4t, 8t and 12t treatments respectively).

The effect of lime on soil pH is shown in Figure 3. The pH significantly increased to 7.22 from an initial value of 5.12. This change had consequent effects on the availability of micronutrients, as has
been explained by other workers (Brady 1990). pH also had an effect on soil organisms (Saha et al. 1999).

Figure 1 Effect of lime on soil Zn, Cu and B with time

Lime application has several consequences on the soil. Since the pH is increased, the solubility of Cu, Zn, Fe and Mn decreases through a complex set of reactions involving precipitation, solubility, change
in microbial populations, etc. Total inorganic Fe in soil solution varies with pH and reaches a minimum in the pH range of 6.5 to 8.0.

\[ \text{Fe}^{+++} + 3 \text{OH}^{-} \rightarrow \text{Fe(OH)}_3 \]

The Fe activity in solution decreases 1000 fold for each unit increase in pH (Lindsay 1973). The values reported in the literature for Mn solubility in soil is highly variable and pH dependent (Geering et al. 1969; Bohn 1970). The predominant species of Zn below pH 7.7 is Zn \(^{2+}\) and above this pH the neutral species, Zn(OH)\(_2\), is predominant. The solubility of Zn is highly pH dependent and decreases 100 fold for each unit increase in pH. Zn deficiency induced in acid soils by excessive liming is in fact explained by this relationship. At low pH values, some Zn \(^{2+}\) may be present on the exchange complex of soils, but at higher pH values the concentration of Zn falls, and very little Zn \(^{2+}\) is present on the exchange complex. Below pH 7.3, Cu exists mainly as Cu \(^{++}\), whereas above pH 7.3, Cu (OH)\(^{+}\) is the most abundant. Organic matter plays a very important role in the solubility of Cu in the soil, because the complex between Cu and organic matter is very strong. Solubility of B is strongly influenced by absorption of B on oxides of Fe and Al (Simms and Bingham 1968). The results obtained in this experiment are not very easy to explain because, as discussed above, the reactions of trace elements in soil are highly complex. Liming and pH changes can only partly explain these phenomena.

The potato tuber yields (fresh weight), in t ha\(^{-1}\), for the various lime levels are given in Table 1.

**Table 1** Effect of lime on yield of two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha(^{-1})</th>
<th>Yield tha(^{-1}) Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>19.4 ± 1.11</td>
</tr>
<tr>
<td>4</td>
<td>23.2 ± 0.88</td>
</tr>
<tr>
<td>8</td>
<td>20.2 ± 0.56</td>
</tr>
<tr>
<td>12</td>
<td>19.1 ± 0.61</td>
</tr>
</tbody>
</table>

In general, application of lime increased yield of tubers. The 4 t ha\(^{-1}\) treatment gave the highest increase in yield of 14.1% for Delaware and 5.3% for Up-to-Date in comparison to the control. With the 8 t ha\(^{-1}\) treatment the increase was 5.6% and 7.0%, respectively. 12 t ha\(^{-1}\) in fact depressed yields as compared to control. All the differences were statistically significant at the 5% level. Similar work done by Shanmugasundaram and Nanian (1993) has shown that potato responded to lime application and highest yield was obtained in the 20 t/ha lime treatment, and different varieties of potato respond differently to liming. In the present work, no significant differences were found in the yield of the 2 varieties of potatoes.

The effect of lime on protein of tubers is shown in Table 2. Protein content of both Delaware and Up-to-Date increased with application of lime. Again highest increase was observed at the 4 t ha\(^{-1}\) level, for Delaware (14.8%). However, for Up-to-Date the highest increase was observed at the 8 t level treatment (15.6%). Protein content is correlated with nitrogen uptake, and lime is known to have beneficial effects on rate of nitrification in soils (Brady 1990).

**Table 2** Effect of lime on protein (%) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime t ha(^{-1})</th>
<th>Protein % Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>8.1 ± 0.39</td>
</tr>
<tr>
<td>4</td>
<td>9.3 ± 0.19</td>
</tr>
<tr>
<td>8</td>
<td>9.1 ± 0.15</td>
</tr>
<tr>
<td>12</td>
<td>8.2 ± 0.23</td>
</tr>
</tbody>
</table>
Effect of lime on nutrient content of soil, yield and nutrient content of potato and infestation by leafminers. B. Lalljee and S Facknath

Figure 2 Effect of lime on soil Fe and Mn with time

Figure 3 Effect of lime on soil pH
Highest values of starch were for the 4 t ha\(^{-1}\) treatment for both varieties (Table 4) and the increases were 22.9 and 17.2\% for Delaware and Up-to-Date respectively, as compared to control. These results show that for potatoes which are going to be used for chips, and French fries, liming could be used to improve quality.

<table>
<thead>
<tr>
<th>Lime tha(^{-1})</th>
<th>Ash % Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>8.2 ± 0.31</td>
</tr>
<tr>
<td>4</td>
<td>9.2 ± 0.11</td>
</tr>
<tr>
<td>8</td>
<td>9.7 ± 0.24</td>
</tr>
<tr>
<td>12</td>
<td>10.1 ± 0.18</td>
</tr>
</tbody>
</table>

**Table 3** Effect of lime on ash (%) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha(^{-1})</th>
<th>Starch % Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>47.6 ± 1.49</td>
</tr>
<tr>
<td>4</td>
<td>58.5 ± 2.65</td>
</tr>
<tr>
<td>8</td>
<td>55.9 ± 1.37</td>
</tr>
<tr>
<td>12</td>
<td>49.7 ± 1.23</td>
</tr>
</tbody>
</table>

**Table 4** Effect of lime on starch (%) in two varieties of potato

Tables 5 to 7 show the effects of lime on the contents of Zn, Cu and Fe. These elements decrease with addition of lime. Percentage decreases for the highest lime treatment for the 2 varieties were 29.9 and 21.9; 44.2 and 39.2, and 14.3 and 13.3\%, respectively.

<table>
<thead>
<tr>
<th>Lime tha(^{-1})</th>
<th>Zinc mg kg(^{-1}) Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>22.1± 0.68</td>
</tr>
<tr>
<td>4</td>
<td>19.4 ± 0.24</td>
</tr>
<tr>
<td>8</td>
<td>17.7 ± 0.11</td>
</tr>
<tr>
<td>12</td>
<td>15.5 ± 0.16</td>
</tr>
</tbody>
</table>

**Table 5** Effect of lime on zinc (mg kg\(^{-1}\)) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha(^{-1})</th>
<th>Copper mg kg(^{-1}) Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>6.1 ± 0.16</td>
</tr>
<tr>
<td>4</td>
<td>5.0 ± 0.06</td>
</tr>
<tr>
<td>8</td>
<td>4.2 ± 0.06</td>
</tr>
<tr>
<td>12</td>
<td>3.4 ± 0.19</td>
</tr>
</tbody>
</table>

**Table 6** Effect of lime on copper (mg kg\(^{-1}\)) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha-1</th>
<th>Iron mg kg(^{-1}) Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
</tr>
<tr>
<td>0</td>
<td>47.6 ± 0.80</td>
</tr>
<tr>
<td>4</td>
<td>44.2 ± 0.32</td>
</tr>
<tr>
<td>8</td>
<td>42.5 ± 0.42</td>
</tr>
<tr>
<td>12</td>
<td>40.8 ± 0.19</td>
</tr>
</tbody>
</table>

**Table 7** Effect of lime on iron (mg kg\(^{-1}\)) in two varieties of potato
Effect of lime on nutrient content of soil, yield and nutrient content of potato and infestation by leafminers.  B. Lalljee and S Facknath

Table 8  Effect of lime on calcium (%) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha⁻¹</th>
<th>Calcium (%)</th>
<th>Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
<td>Up-to-Date</td>
</tr>
<tr>
<td>0</td>
<td>0.9 ± 0.03</td>
<td>0.9 ± 0.01</td>
</tr>
<tr>
<td>4</td>
<td>1.0 ± 0.03</td>
<td>1.2 ± 0.08</td>
</tr>
<tr>
<td>8</td>
<td>1.5 ± 0.14</td>
<td>1.5 ± 0.06</td>
</tr>
<tr>
<td>12</td>
<td>1.9 ± 0.06</td>
<td>1.9 ± 0.09</td>
</tr>
</tbody>
</table>

Table 9  Effect of lime on phosphorus (mg kg⁻¹) in two varieties of potato

<table>
<thead>
<tr>
<th>Lime tha⁻¹</th>
<th>Phosphorus mg kg⁻¹</th>
<th>Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
<td>Up-to-Date</td>
</tr>
<tr>
<td>0</td>
<td>85.9 ± 0.66</td>
<td>84.6 ± 0.95</td>
</tr>
<tr>
<td>4</td>
<td>85.0 ± 1.41</td>
<td>83.2 ± 1.47</td>
</tr>
<tr>
<td>8</td>
<td>80.6 ± 0.81</td>
<td>79.6 ± 0.86</td>
</tr>
<tr>
<td>12</td>
<td>80.4 ± 1.77</td>
<td>80.3 ± 1.00</td>
</tr>
</tbody>
</table>

Table 10  Effect of lime on preference of Liriomyza to host leaves

<table>
<thead>
<tr>
<th>Lime tha⁻¹</th>
<th>No. of insects on potato leaves After 1 hr (n = 35 adults)</th>
<th>Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
<td>Up-to-Date</td>
</tr>
<tr>
<td>0</td>
<td>10.3 ± 1.9</td>
<td>15.5 ± 2.9</td>
</tr>
<tr>
<td>4</td>
<td>7.8 ± 1.6</td>
<td>13.5 ± 1.9</td>
</tr>
<tr>
<td>8</td>
<td>10.5 ± 2.9</td>
<td>10.3 ± 3.8</td>
</tr>
<tr>
<td>12</td>
<td>9.3 ± 2.3</td>
<td>12.8 ± 1.0</td>
</tr>
</tbody>
</table>

Table 11  Effect of lime on infestation by Liriomyza leafminers

<table>
<thead>
<tr>
<th>Lime tha⁻¹</th>
<th>No. of punctures / cm² of potato leaf after 40 h</th>
<th>Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware</td>
<td>Up-to-Date</td>
</tr>
<tr>
<td>0</td>
<td>5.1 ± 1.9</td>
<td>9.3 ± 2.9</td>
</tr>
<tr>
<td>4</td>
<td>3.8 ± 1.6</td>
<td>8.0 ± 2.2</td>
</tr>
<tr>
<td>8</td>
<td>2.2 ± 0.9</td>
<td>6.1 ± 1.8</td>
</tr>
<tr>
<td>12</td>
<td>1.3 ± 0.3</td>
<td>3.2 ± 1.0</td>
</tr>
</tbody>
</table>

This is in accordance with the decrease in availability of these elements in the soil as shown in Figures 1 and 2.  
Effect of lime on calcium in potato tubers is shown in Table 8.  Increases in liming rate increased the calcium content of both varieties of potato.  The 12 t treatment produced the highest level in both varieties.  
Lime depressed the amount of phosphorus in potato tubers of both varieties (Table 9).  The 12 t ha⁻¹ treatment decreased phosphorus by 6.4% and 5.0% for Delaware and Up-to-Date, respectively.  
Addition of lime has an antagonistic effect on availability of phosphorus.  The lowered availability of phosphorus in soil could have resulted in a lower concentration of phosphorus in the tubers.  
As far as influence on insects are concerned, the lime treatment did not significantly change the preference exhibited by Liriomyza spp. adults to potato leaves from treated plants (Table 10).  The number of adults that were attracted to and settled on the treated leaves in caged experiments did not show any difference.  However, the number of punctures, both feeding and oviposition, were significantly different in the various treatments, with a lower number of punctures being observed on leaves from lime treated potato plants (Table 11).  
Studies have indicated that Liriomyza, in common with several species of insects, show distinct preference for nitrogen-rich host leaves.  Potassium is another major nutrient which can have a direct
influence on insect infestation. Phosphorus and calcium, on the other hand, have a negative effect, leaves with lower levels of phosphorus and calcium attracting lower numbers of adult leafminers. The difference observed in the number of adults and punctures on the two varieties of potato could be due to the known varietal preference exhibited by *Liriomyza* to Up-to-Date as compared to Delaware (Facknath in press).

REFERENCES


NG KEE KWONG KF, CAVALOT PC, DEVILLE J. 1993. Cement as an alternative to coral sand for liming acid soils. Rev. Agr. Sucr. L’Ile Maurice. 72(1/2) 50-54


PILOT PLANT INVESTIGATION OF THE TREATMENT OF SYNTHETIC SUGAR FACTORY WASTEWATER USING THE UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) PROCESS

A K Ragen¹, L Wong Sak Hoi¹ and T Ramjeawon²

¹Mauritius Sugar industry Research Institute
²Faculty of Engineering, University of Mauritius

ABSTRACT

The treatment of sugar factory wastewater was studied using a pilot upflow anaerobic sludge blanket (UASB) reactor. The influent was a molasses-based substrate with a chemical oxygen demand (COD) of about 1000 mg l⁻¹. After a successful start-up of the reactor, results showed that with a hydraulic retention time (HRT) at or above four hours and with an average organic loading rate (OLR) below 6.7 kg COD m⁻³.day⁻¹, the COD removal efficiency of the system was over 76%. A sharp drop was observed in the COD removal efficiency at a HRT of two hours and at an average OLR above 11.5 kg COD m⁻³.day⁻¹. The optimum HRT is between four and six hours.

Keywords: Anaerobic wastewater treatment, UASB process, sugar factory effluent.

INTRODUCTION

Mauritian sugar factories will need to treat at least their medium strength wastewaters and/or washings to comply with the standard of 100 mgL⁻¹ COD conformed in the legislation i.e. the Environment Protection Act of 1991. The conventional aerobic wastewater treatment systems would not be appropriate because of the large land space requirement as well as high capital costs (mechanical or diffused aeration systems) and operational costs (energy consumption during aeration and high nutrient requirement).

It is of importance for developing countries such as Mauritius to develop appropriate treatment systems, which combine a high efficiency with simplicity in construction and operation and with some form of valorisation of the pollutants. Such systems are always made up of some anaerobic digestion process (Ramjeawon, 1995). The potential advantages of applying anaerobic technologies for the treatment of industrial wastewater in Mauritius has been recognised (Ministry of Environment and Quality of Life, 1991), specially for sugar cane factory effluents, which are organic and non-toxic, and hence are amenable to anaerobic treatment.

Van Haandel and Lettinga (1994) compared the different existing anaerobic treatment systems. Considering the major drawbacks of the other systems, the upflow anaerobic sludge blanket (UASB) reactor appears to be a potential candidate for the Mauritian sugar mills. Moreover, studies carried out in Mauritius had shown that the UASB process holds much promise as a treatment option for sugar factory wastewaters (Ramjeawon, 1995, Ramdhony 1998).

This paper presents the work done on a 10 L pilot UASB reactor treating synthetic wastewater (diluted molasses). Experiments were conducted to determine the optimum hydraulic retention time (HRT), which is the main operational variable. The results presented in this paper provide some base-line information for the operation of scaled-up UASB reactor for the treatment of sugar mill wastewaters.

MATERIALS AND METHODS

A 10 L UASB pilot reactor was used and the experimental set up is illustrated in Figure 1. The reactor was inoculated with four litres of acclimated sludge and the synthetic wastewater was a molasses-based
solution of about 1000 mg\textsuperscript{l}\textsuperscript{-1} COD. The wastewater was buffered with sodium bicarbonate to prevent drop in pH. Nutrients and trace elements were added in the solution to avoid inhibition of bacterial growth. The reactor was initially started-up with the influent for a period of 65 days.

The reactor was then operated in such a way that the HRT was successively reduced after the reactor had reached the steady-state condition, i.e. when the COD removal efficiency did not vary for more than 5% of the mean value for the last five consecutive days. The operating conditions during that phase are shown in Table 1. It is to be noted that from day 37 to 44, the reactor was not running due to the breakdown of the thermostat of the water bath.

<table>
<thead>
<tr>
<th>Day Number</th>
<th>HRT Hours</th>
<th>Organic loading rate kg COD m\textsuperscript{-3} day\textsuperscript{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 9</td>
<td>10.1</td>
<td>2.0 - 2.7</td>
</tr>
<tr>
<td>10 - 25</td>
<td>8.3</td>
<td>2.7 - 2.8</td>
</tr>
<tr>
<td>26 - 36</td>
<td>6.2</td>
<td>3.6 - 4.2</td>
</tr>
<tr>
<td>45 - 65</td>
<td>4.0</td>
<td>5.9 - 7.0</td>
</tr>
<tr>
<td>66 - 85</td>
<td>2.0</td>
<td>10.7 - 11.9</td>
</tr>
</tbody>
</table>

Hourly samples of the influent and effluent were taken between 7 a.m. and 4 p.m. each day. Composite samples were made up from these samples and analysed for pH, volatile fatty acids (VFA), alkalinity and COD. The influent samples were also analysed for total Kjeldal nitrogen (TKN), ammonium nitrogen, nitrate-nitrogen, total nitrogen, total phosphorus and sulphate. COD was effected by a semi-micro digestion method followed by colorimetry (Wong Sak Hoi, 1992). The determination of VFA and alkalinity were carried out by the 5 pH end-point titration method (Moosbrugger et al. 1992). The method of Kjeldhal digestion followed by steam distillation (Rayment et al. 1992) was used to determine TKN. Analysis of total P was carried out by the H\textsubscript{2}SO\textsubscript{4}/H\textsubscript{2}O\textsubscript{2} decomposition followed by Murphy and Riley colorimetric finish method (Murphy et al. 1962). Sulphate was analysed by the Hach Sulphaver 4 method using a spectrophotometer. Ammonium and nitrate nitrogen were determined by the steam distillation method (Black et al. 1965). The influent was finally analysed for hard COD by the Germirli et al. method (1991) at the end of the experiment.
RESULTS AND DISCUSSION

The influent was characterised for pH, VFA, alkalinity, TKN, ammonium nitrogen, nitrate nitrogen, total P, sulphate and COD. Organic-N and total N were calculated as (TKN – ammonium nitrogen) and (TKN + nitrate nitrogen) respectively. The results with range and mean are given in Table 2.

Table 2 Characteristics of influent measured during the study

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.5 - 7.9</td>
<td>7.7</td>
</tr>
<tr>
<td>VFA, Hac</td>
<td>0.0 - 84.0</td>
<td>31.0</td>
</tr>
<tr>
<td>Alkalinity, CaCO3</td>
<td>580.0 - 1095.0</td>
<td>742.0</td>
</tr>
<tr>
<td>TKN</td>
<td>21.6 - 34.6</td>
<td>31.4</td>
</tr>
<tr>
<td>Ammonium nitrogen</td>
<td>22.4 - 24.5</td>
<td>23.6</td>
</tr>
<tr>
<td>Nitrate nitrogen</td>
<td>0.0 - 4.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Organic N</td>
<td>8.7 - 10.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Total N</td>
<td>31.1 - 38.5</td>
<td>34.9</td>
</tr>
<tr>
<td>Total P</td>
<td>4.0 - 12.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Sulphate</td>
<td>20.0 - 32.0</td>
<td>26.0</td>
</tr>
<tr>
<td>COD</td>
<td>852.0 - 1150.0</td>
<td>1019.0</td>
</tr>
</tbody>
</table>

The average COD:N:P ratio was 100:3.4:1.0 indicating that the nutrients supplied to the microorganisms were sufficient for their growth, when compared to the minimum requirement of 100:2:0.5. The mean COD/SO₄ ratio was more than 39 showing that problems associated with sulphide were not encountered with the influent. These results indicate that the wastewater characteristics were within the required criteria for the utilisation of UASB reactors as presented by Souza (1986).

Investigations started at a HRT of 10.1 hours with a COD concentration of 1124 mg l⁻¹, representing an organic loading rate of 2.7 kg COD m⁻³.day⁻¹. After steady-state had been attained, the HRT was successively reduced to 8.3, 6.2, 4 and 2 hours. The whole phase took 67 days. During the same period the average organic loading rate increased from 2.3 to 11.5 kg COD m⁻³.day⁻¹. The changes of COD removal efficiency at various HRT’s are shown in Figure 2.

The initial low efficiency at each specific HRT can be attributed to the fact that the acidogens and methanogens bacterial populations had to be acclimated to the new flow regime and the increase in organic loading rate.

It was observed that at low hydraulic regimes, this acclimation period was short, e.g. at HRT of 8.3 hours steady-state was reached only after one operational day. However, with declining HRT and increasing organic loading rate, this adaptation stage was longer as shown in Figure 2 (steady-state was established after five operational days at a HRT of 6.2 hours).

It was also observed that while decreasing the HRT, the interface between the sludge and the clear effluent initially present at low flow rates disappeared. The reactor was considered as a completely mixed one. This was due to the increasing upflow velocity accompanied by higher gas production (depending on organic loading rates) that caused further mixing of the sludge. However, at a HRT of two hours, the upflow velocity was too high for the settler to function properly. The hydraulic conditions were so drastic that sludge flew out of the reactor and effluent was flowing through the biogas port. The air passage was blocked and no gas reading could be recorded at that HRT. There was also formation of scum which had to be removed almost every day.
Figure 2 Changes in COD removal efficiency at HRT of 10.1, 8.3, 6.2, 4.0 and 2.0 hours

The steady-state performance of the reactor under varied HRT is given in Table 3 and illustrated in Figure 3.

Table 3 Average characteristics during steady-state operation of the UASB reactor at varied HRT

<table>
<thead>
<tr>
<th>HRT hours</th>
<th>10.10</th>
<th>8.30</th>
<th>6.20</th>
<th>4.00</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of operational days</td>
<td>9.00</td>
<td>15.00</td>
<td>11.00</td>
<td>21.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Average organic loading rate, kg COD m⁻³ day⁻¹</td>
<td>2.30</td>
<td>2.80</td>
<td>4.20</td>
<td>6.70</td>
<td>11.50</td>
</tr>
<tr>
<td>Upflow velocity, m h⁻¹</td>
<td>0.10</td>
<td>0.12</td>
<td>0.16</td>
<td>0.25</td>
<td>0.49</td>
</tr>
<tr>
<td>Average influent VFA, mg l⁻¹ Hac</td>
<td>57.00</td>
<td>31.00</td>
<td>34.00</td>
<td>12.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Average effluent VFA, mg l⁻¹ Hac</td>
<td>16.00</td>
<td>36.00</td>
<td>39.00</td>
<td>55.00</td>
<td>124.00</td>
</tr>
<tr>
<td>Average influent alkalinity, mg l⁻¹ CaCO₃</td>
<td>600.00</td>
<td>591.00</td>
<td>620.00</td>
<td>923.00</td>
<td>885.00</td>
</tr>
<tr>
<td>Average effluent alkalinity, mg l⁻¹ CaCO₃</td>
<td>647.00</td>
<td>647.00</td>
<td>849.00</td>
<td>927.00</td>
<td>815.00</td>
</tr>
<tr>
<td>Average VFA/alkalinity ratio</td>
<td>0.02</td>
<td>0.05</td>
<td>0.06</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>Average influent COD, mg l⁻¹</td>
<td>969.00</td>
<td>964.00</td>
<td>1086.00</td>
<td>1105.00</td>
<td>957.00</td>
</tr>
<tr>
<td>Average effluent COD, mg l⁻¹</td>
<td>216.00</td>
<td>202.00</td>
<td>253.00</td>
<td>267.00</td>
<td>379.00</td>
</tr>
<tr>
<td>Average COD removal efficiency, %</td>
<td>78.00</td>
<td>79.00</td>
<td>77.00</td>
<td>76.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Maximum COD removal efficiency, %</td>
<td>81.00</td>
<td>80.00</td>
<td>78.00</td>
<td>78.00</td>
<td>62.00</td>
</tr>
</tbody>
</table>

The results show that above a HRT of four hours and below an average organic loading rate of 6.7 kg COD m⁻³ day⁻¹, the % COD removal efficiency was almost independent of the HRT and remained systematically above a mean of 76. However, a sharp drop in the COD removal efficiency was observed at a HRT of two hours and at an average organic loading rate above 11.5 kgCOD m⁻³ day⁻¹ (the efficiency dropped to a mean of 60%). This was concomitant with a similar increase in effluent VFA and a decrease in alkalinity (or higher VFA / alkalinity ratio) as presented in Table 3.
The results obtained by Yang et al. (1991), Ramjeawon (1995), Ramdhony (1998) and this study under varying conditions are compared in Table 4.
Table 4  Comparison of reactor performance

<table>
<thead>
<tr>
<th>Reactor capacity</th>
<th>Optimum HRT</th>
<th>OLR</th>
<th>COD efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hours</td>
<td>kg COD m(^{-3})·day(^{-1})</td>
<td>removal %</td>
</tr>
<tr>
<td>Yang et al.1</td>
<td>10.2 l</td>
<td>4.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Ramjeawon2</td>
<td>1 m(^3)</td>
<td>6</td>
<td>12.5</td>
</tr>
<tr>
<td>Ramdhony3</td>
<td>10 l</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>Present study4</td>
<td>10 l</td>
<td>4</td>
<td>6.7</td>
</tr>
</tbody>
</table>

1: Sugar mill wastewater under lab conditions
2: Sugar mill wastewater under industrial conditions
3: Pure sucrose synthetic wastewater
4: Molasses substrate

The HRT and organic loading rate obtained by Yang et al. (1991) and Ramdhony (1998) are comparable with the results obtained in this study, but their efficiencies of COD removal are higher. This is attributed to the fact that they employed a much more biodegradable feed substrate, e.g. Ramdhony used a pure-sucrose solution which is highly biodegradable (max 98%).

Ramjeawon (1995) obtained a longer HRT at six hours, a higher organic loading rate of 12.5 kg COD m\(^{-3}\)·day\(^{-1}\) and an efficiency of 91 % COD removal with a 1 m\(^3\) UASB reactor for treating sugar factory waste water under industrial conditions. The higher organic loading rate was due to a higher influent concentration.

The COD removal efficiency (E) of the UASB reactor at a temperature of 39 °C can be approximated by the following equation, found through regression analysis of the data obtained under steady-state conditions.

\[ E = 1 - 0.47 (\text{HRT})^{-0.37} \]  
(for average COD removal efficiency)

Where HRT is in hours, and lies between 2 and 10.1.

Some empirical equations proposed after the study of the influence of HRT on steady-state UASB reactor efficiency are given in Table 5. The data show that there is a considerable difference in the relationship between efficiency of COD removal and HRT. This may be attributed to the differences in HRT imposed, in the characteristics of the wastewater (domestic and sugar mill wastewater) and in operational conditions. However, it is clear that, except for Ramdhony, there is a general trend towards the following relationship.

\[ E = 1 - a (\text{HRT})^{-b} \]

Table 5  Relationship obtained by various workers between COD removal efficiency (E) and HRT

<table>
<thead>
<tr>
<th>Workers</th>
<th>Relationship between E and HRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aisse &amp; Bollman1</td>
<td>( E = 1 - 1.53 \text{HRT}^{-0.64} )</td>
</tr>
<tr>
<td>Kasking (1989)1</td>
<td>( E = 1 - 0.68 \text{HRT}^{-0.68} )</td>
</tr>
<tr>
<td>Ramjeawon (1995)</td>
<td>( E = 1 - 1.98 \text{HRT}^{-1.32} )</td>
</tr>
<tr>
<td>Ramdhony (1998)</td>
<td>( E = -0.03 \text{HRT}^2 + 0.53 \text{HRT} + 91.72 )</td>
</tr>
<tr>
<td>Present study</td>
<td>( E = 1 - 0.47 \text{HRT}^{-0.37} )</td>
</tr>
</tbody>
</table>

Where a and b are empirical constants which are specific to each UASB reactor and the conditions employed. This general expression can be used to compare the HRT and hence the volume of UASB reactors.

Ramjeawon (1995) stated that it is feasible to design a UASB reactor for treating the medium strength cane sugar mill wastewater at a HRT of six hours to effectively remove up to 90% of the COD at an average organic loading rate of 12.5 kg COD m\(^{-3}\)·day\(^{-1}\). However, in the present study the efficiency
of COD removal at a HRT of six hours was only 78% at an organic loading rate of 4.2 kg COD m$^{-3}$ day$^{-1}$. The difference in efficiency is attributed to the non-biodegradable fraction (inert soluble fraction) of the molasses solution, which passed through the UASB reactor unaffected.

In fact, this inert soluble COD fraction of the molasses solution was found to be 16% of the total COD. This value is comparable to the hard COD of chemical and textile wastewater found at 22 and 25% of total COD respectively (Dosooey, 1998). The effluents from chemical and textile plants are among those which are the most difficult to treat biologically. Dosooey (1998) also reported a value of 2.5% for the inert soluble COD in sugar factory effluent, indicating the highly biodegradable nature of this type of wastewater.

Had there not been such a high amount of inert soluble COD fraction in the molasses feed substrate utilised in this study, the COD removal efficiency would have been more than 90% at a HRT of six hours.

The results also indicate that there was little benefit in operating the reactor at a HRT exceeding four to six hours because no significant additional COD removal was achieved. The optimum HRT for a UASB therefore lies between four and six hours.

However, the optimum HRT to be applied depends on the desired results and whether a post treatment is applied. If the UASB reactor is employed as the only or main treatment unit, the optimum HRT should be sufficiently high to guarantee a high removal efficiency and consequently a HRT of six hours is required. In case if the UASB reactor is used as a pre-treatment unit, shorter HRT can be applied and are advantageous under certain circumstances (Van Haandel and Lettinga, 1994).

Although the efficiency decreases with shorter HRT, in no case was process failure observed (i.e. there was no collapse of the methanogenic activity due to an excessively short retention time). It can be stated that the UASB reactor is very stable under the loading and other conditions applied in the system.

It should be noted that the effluent quality in terms of COD obtained means that compliance with the effluent standard for discharge into rivers would not be met, indicating that a post-treatment will be required when treating sugar mill wastewater with the UASB reactor. This is in line with the observations of Ramjeawon (1995) and Ramdhony (1998).

CONCLUSION

The following conclusions can be drawn from this study:

- HRT, the main operational variable in a UASB reactor, affects directly the COD removal efficiency.
- The optimum HRT is between four and six hours and the choice depends on the desired effluent quality and whether post-treatment is needed.
- The presence of inert soluble COD (hard COD) in the wastewater lowered the COD removal efficiency.
- It is technically feasible to design a UASB reactor to treat sugar factory wastewater at 90% COD removal efficiency at a HRT of six hours and the organic loading rate would depend on the influent COD.
- To achieve compliance with the effluent discharge standards using a UASB reactor, a post-treatment should be applied.
Pilot-plant investigation of the treatment of synthetic sugar factory wastewater using the upflow anaerobic sludge blanket (UASB) process A K Ragen et al.

REFERENCES


LES VITAMINES DU GROUPE B DE QUELQUES VARIETES DE RIZ MALGACHES EN PROVENANCE DE MAROVOAY ET DE TULEAR: MISE AU POINT DE LA METHODE ET DETERMINATION QUANTITIVE

Rasoazanakolona Voahanginirina

FOFIFA

RESUME

Globalement, quelques variétés sont trouvées pourvues de presque toutes ces vitamines (NDR 80, HB96, Basmati, riz rouge), si la pyridoxine est absente dans toutes les variétés.
La méthode utilisée pour le dosage est la chromatographie HPLC de pair d’ion, à phase inversée avec un détecteur ultra-violet. La technique analytique est une programmation de débit entre 0,5 ml et 2,1 ml par minute à des intervalles variées. Ainsi, nous avons pu doser à la fois 4 vitamines du groupe B dans un même échantillon: c’est à la fois un gain de temps, une économie solvants et de fournitures.
Les vitamines PP, B2, et B1 sont plus abondantes dans les variétés blanches vulgarisées de Marovoay et de Tulear que dans les 2 variétés du Moyen-Est utilisées comme substrats de référence. Les résultats ont été obtenus à partir de la moyenne de 2 analyses et ont été comparées avec les données de la littérature. Les chiffres trouvés pour un même lot d’origine se regroupent autour d’une même valeur moyenne.

Mots clés: HPLC, riz, consommation locale, mise au point, vitamines B, détermination quantitative, analyse multidimensionnelle des données.

INTRODUCTION

Le riz tient une place importante dans l’alimentation des Malgaches. La consommation annuelle à Madagascar, bien qu’en déclin, atteint 130 kg. Il est bien connu que les Malgaches sont les premiers consommateurs mondiaux de riz. C’est un plat généralement rencontré dans ses 3 repas principaux.
Des efforts ont été portés sur l’amélioration en quantité de la production nationale. Malheureusement, les alinées climatiques et circonstancielles n’ont pas permis d’atteindre cet objectif. Dans le cadre de son programme national, le FO.FI.FA a voulu joindre ces derniers temps la recherche sur la qualité des grains de riz comme activités de recherche. C’est ainsi que nous avons pu entamer la recherche sur les qualités technologiques des grains de riz: qualité nutritionnelle, culinaire, organoleptique.
Les vitamines du groupe B sont assez intéressantes dans le riz moyennement blanchi; le son très doux issu du pilonnage du riz est même consommé dans les zones rurales pour les enfants assez faibles pour leur préserver du béribéri. La partie du riz provenant du péricarpe jusqu’à la couche à aleurone est riche en vitamines B et E, en matières minérales, et en fibres alimentaires nutritives (Bayonove, 1980). Dans le présent article, nous traiterons la détermination qualitative et quantitative des vitamines du groupe B de quelques variétés de riz vulgarisées dans les zones Nord-Ouest et Sud-ouest de l’île.
MATERIELS ET METHODES

Matériels

Les variétés étudiées ont été fournies par le Centre de Recherche Régional du FOFIFA à Mahajanga et à Tuléar. Les variétés basmati et riz rouge ont été achetées chez un producteur. Les analyses sont faites à partir de riz blanchi des variétés de caractéristiques suivantes: riz irrigué, de cycle allant de 110 jours à 165 jours, d’un rendement à l’ha de 4 à 6 tonnes.

<table>
<thead>
<tr>
<th>Origine: Marovoay</th>
<th>Origine: Tuléar</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° de collection</td>
<td>Nom vulgaire</td>
</tr>
<tr>
<td>X372</td>
<td>Kelimirefaka</td>
</tr>
<tr>
<td>NDR 80</td>
<td>Mahavonj</td>
</tr>
<tr>
<td>X398</td>
<td>Tsiresindrano</td>
</tr>
<tr>
<td>X415</td>
<td>Mampiherika</td>
</tr>
<tr>
<td>X360</td>
<td>Mahadigny</td>
</tr>
<tr>
<td>IR38</td>
<td>Miafimboa</td>
</tr>
</tbody>
</table>

Les vitamines ont été fournies par FARMAD (vitamines B1,B2,PP,B5,B6). Les vitamines H et B9 sont des produits SIGMA.

Méthodes

Les vitamines B1, B2, PP, B6, B5, B9 et H ont été déterminées par HPLC. Le solvant utilisé est un mélange de 9% de méthanol, 10 cc d’acide acétique glacial, et 600 cc d’eau distillée. Ce solvant a été additionné de pics 5 (pentane sulfonic acid) et 8 (octane sulfonic acid), et le tout est filtré à travers un filtre de 0.45µm et désaéré par agitation (Toma RB. et al. 1979).

Le HPLC est équipé d’une pompe à système de contrôle et à phase inversée, d’un injecteur à boucle de 5 µl et d’un détecteur à absorbance ultra-violette.

Pour B1, B2, PP, B5, et B6: la longueur d’onde utilisée est 254 nm
Pour B9 (acide folique): la longueur d’onde est 244 nm
Pour H (biotine): la longueur d’onde est 214 nm.

La colonne utilisée est une colonne C18 de 25 cm de long et de 4,6µm de phase Lichrosorb (Collmer K et Davies L. 1974).
La phase mobile est constituée par l’éluant pompé à travers la colonne avec un débit programmé entre 0.5 ml et 2.1 ml par minute.
Les surfaces de pics sont calculées à l’aide d’un intégrateur électronique. Les valeurs quantitatives ont été obtenues contre une injection de mélange standard de vitamines.

Préparation des échantillons

Les échantillons de riz blanchi (5g) ont été cuits 30 minutes au bain-marie bouillant dans 25 ml de solution H₂SO₄ 0.1N. Après refroidissement, le contenu est ajusté vers PH 4.5 avec de l’acétate de sodium 2,5M. On ajoute ensuite 0.1 g de takadiastase et l’on garde une nuit à 35°C. L’échantillon est filtré à travers un filtre micropore de 0.5µm et dilué à 50 ml par de l’eau distillée. 100µl de ce filtrat est injecté dans l’injecteur à boucle (Toma R.B et al. 1979).
RESULTATS ET DISCUSSION

Sur le choix des conditions expérimentales

Extraction

L’extraction des vitamines a été réalisée par voie mixte utilisant à la fois H$_2$SO$_4$, 0,1 N et une enzyme, la takadiastase. Nous avons d’abord effectué une hydrolyse acide à chaud (90°C) et c’est après refroidissement et ajustement du PH à 4.5, que la takadiastase est ajoutée ; une incubation à 35°C pendant une nuit (12H) permettra d’extraire par la suite plusieurs vitamines dans un même échantillon (Babusiaux C 1987).

Détermination

Les méthodes d’analyse généralement appliquées pour le dosage des vitamines par HPLC utilisent des déTECTeurs fluorométriques (Babusiaux C., 1987) , bien que chers, sophistiqués et par ailleurs fragiles. Notre méthode utilisant le détecteur ultra-violet (plus fréquent dans le pays),présente l’avantage supplémentaire d’effectuer un dosage simultané de 4 vitamines B1, B2, B6, PP. Un étalonnage externe a été établi avec les réactifs de référence. Le mélange obtenu de solution étalon contient: B2=8.50 mg, B1= 4.43 mg, PP= 5.7 mg et B6= 9.16 mg /50ml. Une bonne séparation des 4 vitamines a été réalisée en réglant le débit du solvant selon une programmation 0 - 5 mn = 0.5 ml m$^{-1}$

- 5 - 10 mn = 1 ml mn$^{-1}$
- 10 - 15 mn = 1.5 ml mn$^{-1}$
- 15 - 30 mn = 2.1 ml mn$^{-1}$

B2 sort en premier à $t = 7.51$ mn avec une bande de 0.2 mn
B1 $t = 10.21$ mn 0.3 mn
PP $t = 13.35$ mn 0.4 mn
B6 $t = 19.39$ mn 0.3 mn

Sur les résultats d’analyses

D’après les résultats, il y a variation de la teneur en vitamines selon les variétés: Tableau 1. Dans les variétés de Marovoay, NDR 80 et X372 sont les plus pourvus autant en vitamines B1 que PP. La variété NDR 80 détient le premier rang dans la teneur en vitamines B1 , PP, acide folique, biotine, et acide pantothénique. La teneur en vitamine B2 en est malheureusement trouvée la plus faible parmi toutes les variétés de Marovoay.

Pour les variétés de Tuléar, HB 96 contient les 6/7 des vitamines analysées, tandis que X21 est peu pourvu de vitamines B.

Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative  
Rasoanankolona Voahanginirina

Tableau 1  Richesse en vitamines B des variétés de riz

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Marovoay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X372</td>
<td>0.04</td>
<td>2.72</td>
<td>9.0</td>
<td>0.00</td>
<td>4.08</td>
<td>0.48</td>
<td>0.0</td>
</tr>
<tr>
<td>NDR 80</td>
<td>0.34</td>
<td>5.34</td>
<td>10.9</td>
<td>0.37</td>
<td>9.90</td>
<td>1.13</td>
<td>0.0</td>
</tr>
<tr>
<td>X415</td>
<td>0.28</td>
<td>0.00</td>
<td>3.5</td>
<td>0.00</td>
<td>0.10</td>
<td>0.32</td>
<td>0.0</td>
</tr>
<tr>
<td>X398</td>
<td>0.25</td>
<td>4.04</td>
<td>7.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>X360</td>
<td>0.31</td>
<td>2.79</td>
<td>7.7</td>
<td>0.00</td>
<td>0.28</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>IR38</td>
<td>0.19</td>
<td>0.00</td>
<td>3.9</td>
<td>0.00</td>
<td>0.24</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Tuléar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X21</td>
<td>0.31</td>
<td>0.00</td>
<td>3.3</td>
<td>0.00</td>
<td>0.77</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>2798</td>
<td>0.25</td>
<td>1.74</td>
<td>1.7</td>
<td>0.00</td>
<td>0.04</td>
<td>0.27</td>
<td>0.0</td>
</tr>
<tr>
<td>P882</td>
<td>0.25</td>
<td>0.10</td>
<td>1.8</td>
<td>0.00</td>
<td>0.00</td>
<td>0.25</td>
<td>0.0</td>
</tr>
<tr>
<td>HB96</td>
<td>0.10</td>
<td>2.55</td>
<td>3.8</td>
<td>0.40</td>
<td>0.72</td>
<td>0.44</td>
<td>0.0</td>
</tr>
<tr>
<td>SPR</td>
<td>0.13</td>
<td>0.41</td>
<td>4.0</td>
<td>0.00</td>
<td>0.86</td>
<td>0.10</td>
<td>0.0</td>
</tr>
<tr>
<td>2787</td>
<td>0.23</td>
<td>2.66</td>
<td>5.0</td>
<td>0.00</td>
<td>0.34</td>
<td>0.59</td>
<td>0.0</td>
</tr>
<tr>
<td>Moyen-Est</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basmati</td>
<td>0.02</td>
<td>0.98</td>
<td>2.9</td>
<td>0.12</td>
<td>1.32</td>
<td>0.05</td>
<td>0.0</td>
</tr>
<tr>
<td>Rouge</td>
<td>0.03</td>
<td>0.12</td>
<td>0.6</td>
<td>0.32</td>
<td>2.58</td>
<td>0.10</td>
<td>0.0</td>
</tr>
<tr>
<td>Littérature (riz brun cru)</td>
<td>0.06</td>
<td>0.36</td>
<td>7.0</td>
<td>1.70</td>
<td>0.03</td>
<td>12.00</td>
<td>0.9</td>
</tr>
<tr>
<td>Besoins /</td>
<td>1.70</td>
<td>1.40</td>
<td>18.0</td>
<td>7.10</td>
<td>0.20</td>
<td>0.1-0.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Analyse de données multidimensionnelles.

L’analyse de variance a montré en général une différence significative ( probabilité<0.05) entre toutes ces variétés. La teneur en vitamines B varie selon la variété étudiée: Tableau 2.

Tableau 2  Valeurs limites et moyennes des teneurs en différentes vitamines B de l’ensemble des variétés de riz.

<table>
<thead>
<tr>
<th>Teneur mg/100g</th>
<th>Minimum.</th>
<th>Maximum</th>
<th>Moyenne</th>
<th>Ecart-type ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0</td>
<td>4.16</td>
<td>1.317</td>
<td>1.363</td>
</tr>
<tr>
<td>B2</td>
<td>0.012</td>
<td>6.00</td>
<td>0.553</td>
<td>1.368</td>
</tr>
<tr>
<td>PP</td>
<td>0.400</td>
<td>12.00</td>
<td>4.627</td>
<td>3.110</td>
</tr>
<tr>
<td>B5</td>
<td>0</td>
<td>0.50</td>
<td>0.087</td>
<td>1.155</td>
</tr>
<tr>
<td>B9</td>
<td>0</td>
<td>9.98</td>
<td>1.516</td>
<td>2.679</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>1.15</td>
<td>0.266</td>
<td>0.315</td>
</tr>
</tbody>
</table>

Ce fait peut s’expliquer car la teneur en vitamines B du grain serait sensible à l’eau, à la lumière, et pourra être sensible à l’environnement de la plante, à part les influences des facteurs génétiques. L’effet du site de culture n’est pas significatif, sauf pour la vitamine PP, où elle est la plus forte pour Marovoay et la plus faible pour la zone du Moyen-Est. Les teneurs des autres différentes vitamines B (B1, B2, B5, B9, H) des variétés de riz ne varient pas en fonction des sites géographiques Marovoay ou Tuléar (site proche de la côte chaude peu pluvieuse) ou Moyen –Est (Haut-Plateau) Tableau 3.
Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative Rasoazanakolona Voahanginirina

Tableau 3  Teneurs limites et moyennes en vitamines selon l’origine des variétés mg pour 100g (Rasoazanakolona V 1999)

<table>
<thead>
<tr>
<th>Vitamines</th>
<th>Marovoay</th>
<th>Tuléar</th>
<th>Moyen-Est</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Moy</td>
</tr>
<tr>
<td>B1</td>
<td>0</td>
<td>5.34</td>
<td>2.48</td>
</tr>
<tr>
<td>B2</td>
<td>0.04</td>
<td>0.34</td>
<td>0.15</td>
</tr>
<tr>
<td>PP</td>
<td>3.5</td>
<td>10.90</td>
<td>7.00</td>
</tr>
<tr>
<td>B5</td>
<td>0</td>
<td>0.37</td>
<td>0.06</td>
</tr>
<tr>
<td>B9</td>
<td>0</td>
<td>4.08</td>
<td>2.43</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>1.13</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Analyse en composantes principales (ACP)

Nous avons utilisé cette méthode pour analyser le tableau de données quantitatives constituées par les 14 échantillons pour lesquels nous disposons de 15 variables mesurées: % de brisures, humidité, amyllose, teneur en protéines brutes, en amidon, en cellulose brute, en lipides totaux, en sucres réducteurs, en sucres totaux, en matières minérales, en vitamines B1, B2, PP, B5, B9 et H. (Tableau 4)

Tableau 4  valeurs nutritionnelles des variétés de riz(Rasoazanakolona V, 1998)

<table>
<thead>
<tr>
<th>Variétés</th>
<th>Brûlures %</th>
<th>H2O</th>
<th>Amylose</th>
<th>Matieres Protéiques</th>
<th>Amidon</th>
<th>cellulose</th>
<th>Lipides</th>
<th>Sucres réducteurs</th>
<th>Sucres totaux</th>
<th>Matière minimum</th>
<th>Vitamine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marvoay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X372</td>
<td>12.8</td>
<td>12.6</td>
<td>21.38</td>
<td>7.6</td>
<td>73.2</td>
<td>0.5</td>
<td>0.44</td>
<td>0.44</td>
<td>1.50</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>X398</td>
<td>13.1</td>
<td>12.2</td>
<td>22.59</td>
<td>6.1</td>
<td>75.5</td>
<td>0.5</td>
<td>0.61</td>
<td>0.91</td>
<td>2.69</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td>X415</td>
<td>15.2</td>
<td>12.1</td>
<td>19.46</td>
<td>6.3</td>
<td>77.2</td>
<td>0.5</td>
<td>0.48</td>
<td>0.50</td>
<td>2.63</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>X360</td>
<td>13.7</td>
<td>12.6</td>
<td>22.85</td>
<td>9.1</td>
<td>73.2</td>
<td>0.2</td>
<td>1.78</td>
<td>1.16</td>
<td>1.95</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>IR38</td>
<td>58.9</td>
<td>12.5</td>
<td>20.29</td>
<td>6.7</td>
<td>78.0</td>
<td>0.3</td>
<td>0.65</td>
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<td>70.1</td>
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<td>0.86</td>
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C’est une technique permettant la classification des produits naturels.
Nous avons utilisé cette méthode pour analyser le tableau de données quantitatives constituées par les 14 échantillons pour lesquels nous disposons de 15 variables mesurées: % de brisures, humidité, amyllose, teneur en protéines brutes, en amidon, en cellulose brute, en lipides totaux, en sucres réducteurs, en sucres totaux, en matières minérales, en vitamines B1, B2, PP, B5, B9 et H (Ralambofetra E. 1983).

161
Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative  
Rasoazanakolona Voahanginirina

L’A.C.P. permet de décrire et de classer l’ensemble des échantillons dans des espaces de dimensions plus réduites. Trois composantes décrivent seulement 73% de l’information.

Tableau 5 Matrice de corrélation des variables

<table>
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<tr>
<th></th>
<th>% Bri</th>
<th>H2O</th>
<th>Amyl</th>
<th>MP</th>
<th>Ami</th>
<th>Cell</th>
<th>Mg</th>
<th>Sr</th>
<th>St</th>
<th>MMIN</th>
<th>B2</th>
<th>B1</th>
<th>PP</th>
<th>B5</th>
<th>B9</th>
<th>H</th>
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</thead>
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<td>Ami</td>
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<td>0.05</td>
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<tr>
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<td>0.43</td>
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<td>0.24</td>
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<td>0.38</td>
<td>0.31</td>
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<tr>
<td>B2</td>
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<td>0.19</td>
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<td>-0.51</td>
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<td>-0.47</td>
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<td>0.25</td>
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<td>0.82</td>
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<td>PP</td>
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<td>-0.52</td>
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<tr>
<td>B5</td>
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<tr>
<td>B9</td>
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<td>-0.25</td>
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<td>0.39</td>
<td>-0.26</td>
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<td>-0.10</td>
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<td>0.63</td>
<td>0.58</td>
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<td>H</td>
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<td>0.05</td>
<td>-0.12</td>
<td>-0.15</td>
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<td>0.08</td>
<td>0.20</td>
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<td>0.54</td>
<td>0.49</td>
<td>0.77</td>
<td>1.00</td>
</tr>
</tbody>
</table>

La matrice de corrélation des variables (Tableau 5) montre une corrélation positive très forte entre B1 et PP, B9 et H négative assez forte entre Matières protéiques et Amidon, % brisures et % Amylose; positive assez forte entre sucres totaux et Sucres réducteurs; Vitamines B1 et H, Vitamines PP et B9; négative moyenne entre Matières protéiques et vitamine B1; Amidon et cellulose brute; Amidon et matières minérales;Cellulose et vitamine B2; Lipides et vitamine B1; Lipides et vitamine PP; positive moyenne entre Vitamines B1 et B9; Vitamines PP et H; Vitamines B5 et B9

Tableau 6 Cercle de corrélation

![Cercle des corrélations : 1 et 2 (50%)](image)
Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative  

Rasoazanakolona Voahanginirina

Le cercle de corrélation dans le plan 1-2 (Tableau 6) montre la distribution des variables selon 4 groupes de composés hautement représentatifs:

- Groupe 1 = vit.PP, B1, B9, H
- Groupe 2 = cellulose, amylose, B5
- Groupe 3 = Matières protéiques, lipides
- Groupe 4 = Amidon, Sucres totaux, sucres réducteurs, brisures, B2.

Les groupes 1 et 3 sont hautement représentatifs de l’axe 2 (2ème composante principale), les groupes 2 et 4, de l’axe 1 (1ère composante principale). Une corrélation négative existe entre le groupe 1 et 3, le groupe 2 et 4.

Ainsi, la représentation des échantillons dans ce repère fait ressortir que: Sur la 2ème composante: NDR 80 présente des teneurs en vitamines PP, B1, B9, H élevées mais à faible teneurs en protéines et lipides. X415 est le contraire de NDR 80.

Sur la 1ère composante principale: les variétés 2798, basmati et riz rouge sont assez pourvues en amylose, cellulose, et vitamine B5, mais pauvres en amidon, sucres réducteurs et totaux, brisures, et vitamines B2. Les variétés IR 38, SPR, P882 sont le contraire de 2798 et consort.

Dans le plan 1-3: on trouve les variables hautement représentatifs suivants:

- groupe 1 = matières minérales, B5, Cellulose, B9
- groupe 2 = Vit. B1, vit. H, H2O.
- groupe 4 = Brisures, sucres réducteurs.

Les groupes 2 et 4 sont négativement corrélés.


La variété X372 est riche en vitamines B1, B9, H et en humidité résiduelle, mais elle est dans les faibles teneurs en brisures et en sucres réducteurs. Elle est le contraire de SPR et X21.

**Dendrogramme**

Un dendrogramme sur les données centrées réduites des variétés (Tableau 7) permet de mieux représenter les variétés, divisibles en 3 classes distinctes:

**Tableau 7** Dendrogramme sur les données centrées réduites entre variétés par classification automatique

[Dendrogramme]
La 1ère classe correspond à Basmati, riz rouge, 2798,X415: variétés des groupes 2 et 3 du plan 1-2 dans le cercle de corrélation (riche en protéines, en lipides, en amylose, en cellulose, en B5, mais pauvres en sucres, en brisures, en amidon, en vitamines B2 et PP. 

- La 2ème classe = NDR 80 
- La 3ème classe = X21, HB96, 2787, P882, SPR, IR38, X360, X398, X372. 
Les variétés X360 et X398 sont voisines de même que SPR et P882 (classe apparentée aux groupes 1 et 4 du plan 1-2): classe riche en vitamines PP,B2, en amidon, sucres, brisures, mais pauvres en cellulose, amylose, vitamine B5.

CONCLUSION

Les vitamines du groupe B sont positivement corrélées entre elles, c’est à dire qu’elles sont présentes ensemble dans une même variété: B1,PP,B9,H,B5. Les vitamines B1 et PP sont négativement corrélées avec les teneurs en lipides: là où les variétés sont riches en lipides, elles sont pauvres en vitamines B1 et PP. 

La vitamine B1 par ailleurs, est également corrélée négativement avec la teneur en protéines brutes; de même la vitamine B2 corrélée négativement avec la richesse en cellulose. 

Les teneurs en amidon et en protéines brutes sont corrélées également négativement dans les grains de riz. Pour des variétés riches en amidon , donc pauvres en protéines , on peut s’attendre à une richesse en vitamines B1. 

Les grains de riz pauvres en éléments minéraux, donc riches en amidon, seront aussi pourvus en vitamine B1. Les variétés de riz pauvres en cellulose brute sont riches en amidon, et riche en B2, en B1 et contiennent aussi toutes les autres vitamines B. Ainsi, une faible teneur en substances nutritives organiques (lipides, cellulose, protéines ), et matières minérales, rend favorable la présence de vitamines B dans les échantillons de riz. L’étude d’une plus grande quantité de variétés permettra de conduire à une conclusion plus rigoureuse de ces corrélations. 

En ce qui concerne le dendrogramme fait à partir des données centrées réduites, la variété NDR 80 constitue à elle seule une classe particulière riche en vitamines B1,PP,B9,H, mais pauvre en lipides et en protéines.

REFERENCES BIBLIOGRAPHIQUES


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APPLICATION D'UN NOUVEAU PROCEDE DE SALAISON A LA VALORISATION DE LA VENAISON

A Collignan, F Deumier et P Grimaud

CIRAD île de la Réunion

RESUME

L'élevage du cerf rusa représente un important marché économique dans les îles Mascareignes, l'essentiel de la venaison est vendu en frais. Aussi, la recherche d'autres voies de valorisation par la transformation pourrait être un facteur supplémentaire du développement de la filière cervine.

La salaison est l'un des plus anciens procédés de conservation de la viande. Elle consiste en l'incorporation de sel et de divers ingrédients dans la viande crue et est souvent associée à des traitements complémentaires (maturation, séchage, fumage...) afin de conférer au produit une bonne stabilité microbiologique et des caractéristiques organoleptiques spécifiques.

L'application de procédés classiques de salaison n'a pas donné satisfaction en raison du caractère particulièrement maigre de la venaison (cerf, daim, etc.) qui s'imprègne beaucoup trop en sel et de la perte des arômessubtils de gibier qui la caractérisent. Différents essais ont été menés en appliquant un nouveau procédé développé par le CIRAD, la Déshydratation-Imprégnation par Immersion (DII). Les premiers résultats, menés sur de la viande de daim, montrent que ce procédé s'applique particulièrement bien à la viande de cervidé (facilité de formulation par contrôle du salage et de la déshydratation du produit, rapidité de traitement, adaptabilité au contexte tropical).

Mots clés: Transformation, viande, venaison, salage, séchage

INTRODUCTION

L'élevage du cerf rusa est principalement présent sur l'île Maurice, avec 650 tonnes de venaison produites annuellement, mais également sur l'île de la Réunion, où le potentiel de commercialisation est estimé à 200 tonnes. Dans ces deux territoires, l'essentiel de la venaison est vendu en frais, et la mise sur le marché d'un produit de diversification pourrait être un facteur supplémentaire du développement de la filière cervine dans les Mascareignes. La transformation est une alternative intéressante dans la mesure où elle apporte une plus-value au produit et en facilite la commercialisation (augmentation de la durée de vie, conditionnement).


D’autre part, la viande de cervidé présente certaines caractéristiques spécifiques comme une faible teneur en graisse (< 2%), une tendreté remarquable et des arômes subtils de gibier. Bien que ces caractéristiques puissent être considérées comme des atouts, les quelques essais de transformation par salage, séchage et/ou fumage qui ont été conduits en mettant en œuvre des procédés classiques n'ont pas donné satisfaction et ce pour plusieurs raisons. Cette viande, particulièrement maigre, s'imprègne beaucoup trop en sel lorsqu'elle est soumise aux conditions classiques de salaison. D'autre part, les arômes de gibier qui la caractérisent ont tendance à disparaître au cours du procédé et la viande à développer des odeurs désagréables après traitement (ammoniac et peptone qui témoignent d’une
dégénération des protéines. Enfin, les nombreux muscles de petite taille, commercialisés en frais, pourraient être valorisés comme produits de grignotage (salés, séchés et aromatisés). L'objectif de ce travail est d'évaluer les possibilités qu'offre la Déshydratation-Imprégnation par Immersion (DII) pour déshydrater, formuler et conserver la viande de venaison.

MATERIELS ET METHODES

Matière première

Les filets de viande utilisés proviennent d'un élevage de jeunes daims de trois ans (Aveyron, France). Leurs caractéristiques sont présentées dans le Tableau 1. La solution ternaire dans laquelle les filets de daim sont immergés est composée d'eau, de sel (NaCl) et de sirop de glucose (Roclys, DE38).

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<th>Tableau 1 Caractéristiques initiales des filets de viande de daim</th>
</tr>
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<tbody>
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<tr>
<td><strong>Teneur en sel</strong></td>
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<tr>
<td><strong>Teneur en matière grasse</strong></td>
</tr>
<tr>
<td><strong>Flore aérobie mésophile totale</strong></td>
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</table>

Méthodologie

Un plan d'expérience basé sur un réseau uniforme de Doehlert (Doehlert, 1970) a été utilisé pour étudier et modéliser l'opération de DII appliquée au daim. La méthodologie des surfaces de réponse a été appliquée pour la représentation graphique et l'optimisation du procédé de DII (Collignan et Raoult-Wack, 1994). Les filets de viande sont placés entre des grilles verticales, immergés dans la solution concentrée et maintenus agités. Les facteurs étudiés sont la concentration en sel (C_{sel}), la concentration en sucre (C_{sucre}) et le temps de traitement (t). La température de traitement est fixée à 10 °C. Les transferts de matière sont exprimés en terme de perte en eau (PE), gain en sel (G_{sel}) et gain en sucre (G_{sucre}).

\[
\text{PE} = \frac{w_u(0) - w_u(t) \cdot M(t)}{M(0)} \quad \text{Eqn [1]}
\]

\[
\text{G}_{\text{sel}} = -w_{st}(0) + w_{st}(t) \cdot M(t) / M(0) \quad \text{Eqn [2]}
\]

\[
\text{G}_{\text{sucre}} = w_{su}(t) \cdot M(t) / M(0) \quad \text{Eqn [3]}
\]

Où

- M(t) masse de l'échantillon au temps t
- w_u(t) teneur en eau du produit au temps t
- w_{st}(t) teneur en sel du produit au temps t
- w_{su}(t) teneur en sucre du produit au temps t.

Analyses physico-chimiques et microbiologiques

La teneur en eau est mesurée par dessiccation dans une étuve à 104 °C pendant 24 heures. La teneur en chlorure de sodium (NaCl) est mesurée à l'aide d'un chlorimètre (Corning chloride analyzer 926), après extraction dans de l'acide nitrique à 0,3 N. Le dosage des sucres (glucose, maltose, maltotriose) est réalisé par HPLC après extraction alcoolique. Les analyses microbiologiques en fin de procédé et en cours de stockage consistent à dénombrer la flore aérobie mésophile totale (FAMT), les coliformes totaux et la charge en levures et moisissures au moyen de tests rapides (Pétrifilm, 3M Santé). Les produits utilisés pour cette étude sont emballés sous vide (emballuse Multivac A 300) dans des sachets thermosoudables en PAPE (PolyAmide-PolyEthylène) et stockés en chambre froide à + 94 °C.
RESULTATS ET DISCUSSION

Analyse des transferts de matière

La Figure 1 représente l’influence de $C_{\text{sel}}$ et $C_{\text{sucre}}$ sur la perte en eau à 5 heures de traitement. Dans le domaine des faibles $C_{\text{sucre}}$ (0 à 950 g/L), la présence de sel dans la solution a un effet significatif sur la perte en eau (jusqu’à 30 %). Par contre, dans le domaine des fortes $C_{\text{sucre}}$, l’influence de $C_{\text{sel}}$ sur la perte en eau devient faible et ce quelle que soit la concentration en sel. Dans ce dernier cas, les niveaux de perte en eau atteints sont aussi importants.

Figure 1 Surface de réponse de la perte en eau (PE) en fonction de la concentration en sel ($C_{\text{sel}}$) et de la concentration en sucre ($C_{\text{sucre}}$) à 5 heures de traitement.

La Figure 2 représente l’influence de $C_{\text{sel}}$ et $C_{\text{sucre}}$ sur le gain en sel à 5 heures de traitement. On constate qu’en l’absence de sucre dans la solution, le gain en sel est proportionnel à $C_{\text{sel}}$ et atteint des niveaux importants (jusqu’à 7%). Par contre, l’ajout de sucre limite l’imprégnation en sel qui devient plus faible pour de fortes concentrations en sucre (4,5%).

Cet effet «barrière» du sucre sur la pénétration du sel a déjà été mis en évidence sur des produits végétaux (Bolin et al., 1983; Lenart et Flink, 1984) et des produits d’origine animale (Favetto et al., 1981 ; Collignan et Raoult-Wack, 1992). Il serait dû à la formation dans l’aliment, d’une couche périphérique fortement concentrée en sucre (Figure 3). L’imprégnation en sucre, quant à elle, est rendue négligeable (< 2%) grâce à l’utilisation de sucrés de forte masse molaire (sirop de glucose, DE38) dont la saveur n’est pas détectée par le consommateur en raison de leur faible pouvoir sucrant. Nous voyons ainsi l’intérêt d’ajouter dans la solution concentrée un soluté supplémentaire, le sucre, pour favoriser la déshydratation du produit tout en contrôlant son imprégnation en sel.

La Figure 4 montre l’évolution de la perte en eau et du gain en sel en fonction du temps pour des conditions optimales de traitement ($C_{\text{sucre}} = 950$ g/L et $C_{\text{sel}} = 175$ g/L) déterminées à partir du modèle polynomial du plan d’expérience. On observe qu’en 15 heures de traitement, les niveaux de perte en eau (≥40%) et de gain en sel (3-4%) correspondent à ceux des produits de salaison du commerce (jambon cru, magret de canard séché, viande des grisons, etc.).
**Figure 2** Surface de réponse du gain en sel ($G_{sel}$) en fonction de la concentration en sel ($C_{sel}$) et de la concentration en sucre ($C_{sucre}$) à 5 heures de traitement.

La viande fraîche utilisée contenait une charge maximum (FAMT) de $24,0 \times 10^3$ UFC g$^{-1}$, ce qui est en accord avec les normes françaises de qualité pour la viande crue, réfrigérée ou congelée. Cette contamination initiale correspond à une valeur logarithmique de 4,4. Il apparait que la DII fait perdre 1,9 unité logarithmique à la charge microbienne du produit (**Figure 5**).L'action bactériostatique et/ou bactéricide de la DII peut s'expliquer par un lessivage de la flore de surface, l'importance de la pression osmotique et le rôle bactériostatique du sel.
Figure 4 Cinétiques de perte en eau et gain en sel obtenues sur des filets de daim immersés à 10 °C dans une solution ternaire de concentrations $C_{\text{sel}} = 175 \text{ g kg}^{-1}$ d'eau et $C_{\text{sucr}} = 950 \text{ g kg}^{-1}$ d'eau.

Figure 5 Evolution de la charge en flore aérobie mésophile totale et en levures et moisissures du produit au cours de stockage

Durée de vie du produit en cours de stockage

Après DII, la charge microbienne diminue, confirmant ainsi l'effet stabilisateur de la DII. Les coliformes totaux étaient absents de la viande fraîche et ne se sont pas développés pendant le stockage. Ceci confirme d’une part la bonne qualité sanitaire de la matière première, et d’autre part la bonne conduite du traitement de DII. Les croissances des FAMT et des levures et des moisissures suivent un schéma classique (Figures 5). Au bout de 14 semaines de stockage, les produits conditionnés sous vide et à 4 °C présentent une qualité sanitaire tout à fait acceptable.
CONCLUSION

Cette étude illustre bien l'intérêt d'appliquer le procédé de DII, en solution mixte sel/sucre et à basse température, au salage/séchage de la viande. Les comportements obtenus corroborent certaines tendances déjà relevées dans la littérature (bonne déshydratation, maîtrise de l'imprégnation en solutés, effet barrière du sucre sur le sel). Une importante déshydratation et un salage contrôlé du produit ont pu être obtenus tout en limitant l'imprégnation en sucre grâce à l'utilisation de sucres de fortes masses molaires (sirop de glucose, DE38). Après plus de 3 mois de stockage, le niveau de contamination des produits reste faible. Ainsi, il apparaît clairement que la DII peut constituer une alternative avantageuse au procédé classique de salage/séchage pour les viandes de venaison. Quelques expériences préliminaires montrent que ces essais réalisés sur le daim sont aisément transférables au cerf rusa qui présente des aptitudes technologiques très proches. Cependant, des études complémentaires sont nécessaires pour apporter une aromatisation finale au produit ainsi que pour industrialiser le procédé qui n’a été validé qu’à l’échelle du laboratoire.

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LE SUIVI DE GESTION RAISONNEE DES PRAIRIES A LA REUNION

P Thomas, V Blanfort, A Michon et P Grimaud

UAFP, CIRAD

RESUMÉ

Le programme «Gestion Raisonnée des prairies» a été initié en 1995 par l’Union des Associations Foncières Pastorales avec l’appui scientifique et technique du CIRAD-Elevage. Financée par le Conseil Régional de la Réunion, cette opération de recherche-développement a débouché sur un service d’appui aux éleveurs de ruminants qui complète logiquement les activités de l’Union des AFP auparavant ciblées sur l’installation et la récolte de surfaces fourragères. La mise en œuvre à l’échelle du développement d’outils de diagnostics permettant de raisonner la fertilisation, la conduite du pâturage tournant et la pérennité des couverts prairiaux, contribue à une gestion durable des prairies. En réponse aux constats de départ, une production très irrégulière en quantité et en qualité au cours de l’année, des pratiques de fertilisation inadaptées, conduisant souvent à la dégradation des prairies, les outils de gestion et les propositions techniques formulées sur la base des résultats obtenus ces six dernières années, constituent donc une aide à la décision personnalisée. Éleveurs et organismes d’encadrement peuvent aujourd’hui concevoir des modes de gestion raisonnée des prairies visant à maîtriser durablement la production d’herbe pour satisfaire des objectifs de production animale concrets tout en gérant et en protégeant des espaces pastoraux aux multiples vocations.

MOTS CLÉS : Ile de la Réunion, gestion raisonnée, prairies, nutrition minérale, biovolume, composition floristique.

INTRODUCTION


Une démarche originale, empruntée à l’écologie systémique, considère les couverts prairiaux comme des "systèmes écologiques complexes pilotés par les éleveurs" (Balent et Stafford-Smith 1991) et faisant intervenir en interaction le milieu, l’homme, l’animal et le végétal. A partir d’observations sur la végétation, intégrateur privilégié, les caractéristiques et le fonctionnement des systèmes herbagers d’altitude réunionnais sont analysés en regard des pratiques des éleveurs au sein des systèmes de production.

Actuellement, 90 éleveurs de bovins, de caprins, d'ovins ou de cerfs, adhérant à ce suivi, conçoivent des modes de gestion des prairies en se référant aux propositions techniques issues des résultats acquis en six ans. Ils se répartissent dans les principales zones d’élevage de l’île: les Hautes Plaines, les Hauts de l'Ouest, du Sud et de l'Est. Cette diversité de situations géographiques permet d’aborder différents contextes pédoclimatiques et systèmes d’exploitation.
MATERIELS ET METHODES

Sur la base du constat de départ qui identifiait deux problèmes majeurs du fonctionnement des systèmes herbagers d'altitude, une production d'herbe très irrégulière au cours de l'année et la non-durabilité des prairies, trois outils de diagnostic ont été mis en œuvre pour répondre à des objectifs concrets des systèmes fourragers à plus ou moins long terme: la maîtrise de la production d'herbe par la fertilisation, son utilisation par les animaux et la pérennité des prairies (Duru et al. 1994).

L'estimation de la masse d'herbe disponible par animal, à cinq périodes de l'année, permet le calcul d'un biovolume exprimé en m³/UGB et quantifie l'équilibre entre la demande de fourrage par le troupeau et l'offre résultant de l'ensemble des parcelles. La mesure de la hauteur d'herbe à l'entrée des animaux sur une parcelle renseigne sur la qualité alimentaire du fourrage mis à la disposition des animaux ; celle à la sortie de la parcelle conditionne sa repousse.

L’analyse minérale de la biomasse herbacée et le calcul d’indices de nutrition pour l’azote, le phosphore et le potassium permettent d’apprécier indirectement la capacité de fourniture du sol. Dérivant des modèles de dilution minérale (Salette et Lemaire 1981), ces indices sont une mesure quantifiée de l’écart entre le niveau de concentration observé et le niveau potentiel théorique de l’élément considéré atteint en condition d’alimentation non limitante (Duru 1992). Les indices de nutrition non limitants ont donc théoriquement une valeur de 100 pour l’azote et le potassium, l’expérience ayant montré qu’un indice de 80 correspondait en fait à un niveau de nutrition non limitant pour le phosphore (Granger 1992). Associés à des analyses de sols, ces indices permettent d’ajuster la fertilisation des prairies à des objectifs de production d’herbe suffisante pour nourrir les animaux tout en évitant le gaspillage d’herbe et d’engrais (lessivage...). Depuis 1995, 1418 échantillons de plante et 563 de sol ont été analysés.

L’étude de la composition floristique d’une parcelle par la méthode des points-quadrats (Daget et Poissonet 1971) permet de la positionner dans un référentiel établi lors de la phase de recherche. Le diagnostic de son état actuel et de son évolution floristique probable est alors possible. La restitution individuelle des résultats est faite sur supports cartographiques où est identifiée chaque parcelle (parcellaire et superficies). Ces restitutions sont effectuées avant chaque changement de saison pour constituer une aide à la décision opérationnelle et dynamique.

RESULTATS ET DISCUSSIONS

Evolution des biovolumes

Dans un premier temps, jusqu’en 1997, un déséquilibre est apparu entre les pratiques de gestion et les rythmes biologiques saisonniers. En saison des pluies, les éleveurs disposaient généralement d’une forte quantité d’herbe de fait exploitée tardivement (Figure 1). À l’inverse, pendant la saison fraîche, le ralentissement de la croissance végétative souvent accentué par une exploitation excessive de l’herbe et une fertilisation inadaptée ont pu quelquefois contribuer à une situation de déficit fourrager momentané. Depuis 1998, la production fourragère est plus régulière dans l’année et de meilleure qualité: les biovolumes se sont davantage rapprochés des références techniques souhaitables grâce à une maîtrise croissante de la ressource herbagère. Cette évolution est particulièrement prononcée pour les exploitations dont le système herbager est à base de kikuyu (Pennisetum clandestinum). Le pic de production de saison des pluies, moins important, se décale vers la fin de saison grâce à une fertilisation moins riche en azote et des pluies tardives favorisant cette tendance. Aucun biovolume mesuré n’excède 2000 m³/UGB : les rythmes d’exploitation de l’herbe étant mieux maîtrisés, les animaux consomment une herbe plus jeune et de qualité accrue pendant la saison chaude, comme le montre l’évolution des teneurs en azote total de la plante, déterminées pour le calcul de l’indice de nutrition azotée, et dont l’augmentation témoigne d’un accroissement de la digestibilité du fourrage lié à de plus fortes proportions de jeunes feuilles. Par ailleurs, des apports fractionnés d’engrais assurent le maintien d’une production herbagère suffisante en saison fraîche habituellement déficitaire en fourrage (pas de minima inférieurs à 200 m³/UGB).

1 Unité Gros Bovin : unité théorique correspondant à une vache laitière de 600 kg produisant 3000 l de lait par an
Diagnostic de fertilité

En saison des pluies, des engrais faiblement dosés en azote, visant à limiter les excédents de fourrage tout en alimentant le sol en phosphore et en potassium selon les besoins exprimés par les diagnostics, conduisent à la diminution des écarts aux références souhaitables: moins d’excès et de carences, baisse des variabilités saisonnières et inter exploitations. En saison fraîche, la stimulation de la pousse de l’herbe ralenti par les conditions hivernales avec des engrais plus fortement dosés en azote est atteinte. L'utilisation de formulations plus adaptées à des doses plus raisonnées se retrouve dans l'évolution des indices de nutrition des prairies depuis 5 ans (Figure 2). Les niveaux azotés des parcelles sont toujours moins élevés en saison des pluies. En saison fraîche les indices de nutrition progressent et permettent la production fourragère nécessaire à l’alimentation du troupeau et au maintien de la qualité de l’herbe et la composition floristique de la prairie. La forte variabilité des niveaux de nutrition en potassium tend à se réduire et la majorité des indices se situe désormais dans une gamme plus restreinte, excès et carences devenant moins prononcés.

Bien que plus lente, la levée des phénomènes de blocage du phosphore dans les andosols devant être envisagée sur le long terme, une nette amélioration des indices de nutrition en phosphore se manifeste en saison fraîche, par la quasi disparition des fortes carences observées les années précédentes. Compte tenu de l’insuffisance d’entretien calco-magnésien, on assiste à une acidification progressive, plus ou moins marquée, des sols (Tableau 1). Ces résultats, qui s’opposent à l’optimisation des pratiques de fertilisation, montrent que l’acidité des sol demeure l’un des principaux facteurs limitant la culture fourragère dans les Hauts de la Réunion.

Figure 1  Evolution des biovolumes dans les exploitations du suivi Gestion Raisonnée des Prairies depuis 1995.

Tableau 1  Répartition des pH observés lors de 3 campagnes d’échantillonnage: pourcentages par catégorie

<table>
<thead>
<tr>
<th>Année</th>
<th>Fortement acide pH &lt; 4.5</th>
<th>Acide 4.5 &lt; pH &lt; 5</th>
<th>Acide à correct 5 &lt; pH &lt; 5.5</th>
<th>Correct pH ≥ 5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>5</td>
<td>22</td>
<td>45</td>
<td>28</td>
</tr>
<tr>
<td>1996</td>
<td>3</td>
<td>31</td>
<td>37</td>
<td>29</td>
</tr>
<tr>
<td>1999</td>
<td>2</td>
<td>37</td>
<td>44</td>
<td>17</td>
</tr>
</tbody>
</table>

Figure 2  Evolution des indices de nutrition minérale sur l’ensemble des parcelles suivies depuis 1995 (SP=saison des pluies; SS=saison fraîche et / ou sèche; en trait rouge: indice non limitant)

Pérennité des prairies

Le suivi de la composition floristique a permis dès 1994 de reconstituer les trajectoires évolutive de la végétation prairiale d’altitude. Ces trajectoires montrent l’influence dominante et structurante des facteurs anthropiques de mise en valeur pastorale et mettent en évidence que la flore des prairies reflète les pratiques de gestion. Deux types de pratiques exercent une influence déterminante sur l’état et l’évolution de la composition de la végétation prairiale. La fertilisation (N,P,K) régit les processus de croissance, le chargement (C) et la fréquence de passage (I) représentent la consommation. La combinaison de ces facteurs induit différentes dynamiques de végétation (exemple de la Plaine des Cafres, Figure 3) :
Le groupe PDC1 des prairies cultivées intensives fait l'objet d'une forte fertilisation (>300 U de N/ha), les fortes productions qui en découlent sont bien contrôlées par des rythmes rapides de pâturage tournant (< 30j) en saison des pluies). On y observe une flore très peu dégradée.

- Le type PDC2 est constitué à la base des mêmes prairies que les précédentes mais avec des pratiques divergentes. La forte fertilisation azotée entraîne des hauteurs d'herbe fortes (>30 cm), indicatrices d'un déséquilibre entre une production d'herbe importante et une faible utilisation (charges plus faibles, fréquence de passage plus longue). Ce déséquilibre entre la production et la consommation entraîne une dégradation des parcelles (cépéracées, Agrostis sp, Cynodon dactylon).

- Le type PDC3 représente des prairies cultivées très dégradées, d'âge divers, peu ou pas fertilisées et faiblement exploitées (charge < 1UGB, Isp> 60j). On y observe un envahissement systématique par la Flouve odorante (Anthoxanthum odoratum). Pour les plus anciennes on note un retour vers la végétation naturelle à Philippia montana ou vers des stades de dégradation non réversibles à Ulex europaeus (l'ajonc).

Le type PDC4 des prairies naturelles est localisé dans des zones à fortes contraintes de milieu et d'accès empêchant les pratiques d'entretien. Les variables de milieu les plus contraignantes sont la pente et l'hydromorphie, qui constituent dans les cas extrêmes des contraintes difficilement compensables par des pratiques d'intensification. Le milieu apparaît donc comme un critère de choix de mise en valeur, avec des zones intensifiables (prairies cultivées) et d'autres à réserver à des prairies naturelles moins performantes au niveau agronomique mais moins exigeantes et plus stables.

Figure 3 Plan des axes principaux de l'AFCVI montrant les relations entre les pratiques et la floristique (Cas de la Plaine des Cafres). N,P,K: apport d'azote, phosphore et Potassium. C: charge instantanée annuelle (an), de saison des pluies (sp), de saison sèche (ss).
I: Intervalle entre passage. H: hauteur d'herbe moyenne

CONCLUSION ET PERSPECTIVES

Les premiers résultats ont confirmé l’hypothèse de base des travaux à l'origine de cette opération de recherche-développement. La variabilité des pratiques souvent inadaptées, apparaît alors comme un facteur essentiel des différences de comportement et de performances d'une même ressource fourragère avec des répercussions importantes sur la viabilité et la pérennité des exploitations à dominante herbagère. Cette forte variabilité entre exploitations a rappelé l’intérêt d’un suivi

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EVALUATION OF THE PERFORMANCE OF DEER WEANERS ON THREE DIFFERENT FEED SUPPLEMENTS

H Bheekhee, RK Ramnauth, R Lam Sheung Yuen, R Fakim and B Dobee

Agricultural Research and Extension Unit

ABSTRACT

In Mauritius, deer are farmed on marginal lands that are not suitable for other economic agricultural activities. Pasture production, which is seasonal, gives rise to shortages at certain periods of the year and this is often prolonged during drought spells. To meet the requirements of deer, all farmers have recourse to the use of feed supplementation. Three supplements were evaluated based on the growth performance of young rusa deer from weaning to 9 months post-weaning. These supplements were (a) a commercially produced, concentrate-based reconstituted feed supplement, (b) a combination of sugarcane molasses and cottonseed cake, and (c) a farm-made supplement known as “melabag”. The animals were run separately in one-hectare paddocks containing mostly star grass (Cynodon plectostachyus) pasture. Mean daily growth rates were 129 ± 14 g for stags and 100 ± 8 g for hinds. Animals in all 3 treatments grew to target weights, with hinds exceeding their critical liveweight required at breeding. Economically, the supplement prepared using a commercially produced concentrate was the cheapest in terms of liveweight gain. This was followed by the supplement combining liquid molasses with cottonseed cake. The most widely used locally-made supplement, known as “melabag”, proved to be the most expensive.

Key words: Rusa deer, Cervus timorensis russa, supplementation, growth rate, liveweight, breeding, slaughter.

INTRODUCTION

The success of farming of rusa deer (Cervus timorensis russa) for venison production depends largely on rapid growth rates and good reproductive performance. This is closely associated with the level of nutrition. Deer are ruminant animals, and as such, need pasture for grazing. Since there is a positive relationship between productivity of pasture and rainfall, pasture deficits are bound to occur during periods of drought. The pasture production profile in Mauritius shows strong seasonal characteristics with higher yields during the wet summer months and much lower yields during the relatively drier and cooler winter months (Bheekhee et al., 1998). This often results in an abundance of pasture during the period extending from January to April /May and shortages become significant later on until December. The drought of 1999 has illustrated this high variability and the vulnerability of livestock production systems due to weather uncertainties. Unless irrigation facilities are provided, pasture species grow fast only for a short period and then remain as a standing crop of mature or dry mass with low protein and low metabolizable energy (ME), which eventually gets depleted rapidly. To overcome this problem of pasture deficits, all deer farmers make use of supplements to meet the nutritional requirements of the animals.

In a deer enterprise, supplements are utilised to increase the productivity of the farm by increasing its stocking density to an optimum level. These supplements are often produced on the farms. The ingredients used in the preparation of the feed supplement and the feed’s composition vary from farm to farm. Thus, deer feeding on these supplements shows variable responses. The present trial was conducted to study the effect of 3 feeding regimes, using different supplements, on the growth rate of young deer from weaning till breeding or slaughter age.
Objectives

The objectives of the present study were to determine the growth rate and cost of liveweight gain of weaner rusa deer grazed on star grass (*Cynodon plectostachyus*) and given a supplement, to reach breeding or slaughter weight at an early age.

MATERIALS AND METHODS

The trial was conducted at Constance Deer Farm. Sixty fawns, comprising of 30 males and 30 females from the 1998 fawn drop were randomly selected and weaned on 14th September 1998, at approximately 4 months of age. They were weighed, tagged and treated with Ivermectin. These animals were randomly allocated to 3 groups, each containing 10 males and 10 females. The 3 groups were reared in separate paddocks containing *Cynodon plectostachyus* pasture. Each group was then assigned to one of 3 feeding regimes shown in Table 1.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Feeding regime</th>
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<tbody>
<tr>
<td>Treatment 1</td>
<td>a) Pasture</td>
</tr>
<tr>
<td>(T 1)</td>
<td>b) Reconstituted feed supplement (containing feed concentrate</td>
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<tr>
<td></td>
<td>CaP4) at the rate of 3.0 % bodyweight</td>
</tr>
<tr>
<td></td>
<td>c) Water ad libitum</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>a) Pasture</td>
</tr>
<tr>
<td>(T 2)</td>
<td>b) Sugarcane molasses + Cottonseed cake (300 g h⁻¹ d⁻¹).</td>
</tr>
<tr>
<td></td>
<td>c) Water ad libitum</td>
</tr>
<tr>
<td>Control</td>
<td>a) Pasture</td>
</tr>
<tr>
<td>(T 3)</td>
<td>b) “Melabag”- Farm mixed feed containing molasses, bagasse,</td>
</tr>
<tr>
<td></td>
<td>poultry litter, etc.</td>
</tr>
<tr>
<td></td>
<td>c) Water ad libitum</td>
</tr>
</tbody>
</table>

The trial started on 14th September 1998 and ended on 23rd June 1999.

Pasture

Because of a severe drought condition, there was almost no pasture from September 1998 to February 1999. A little amount of rain permitted some pasture growth as from February 1999. Poor pasture growth and the presence of animals within the grazing grounds made it quite difficult to estimate pasture yield and intake. Standing pasture that was available to deer was estimated to be at 1200 kg DM/ha by the end of March 1999, using quadrats of size 1 m². This declined gradually to almost 750 kg DM/ha⁻¹ at the end of the study, three months later.

Supplements

Animals in Treatment 1 (T1) received a daily supplement which was reconstituted with a commercially produced concentrate (CaP4), at the rate of 1.0 kg/head throughout the study. The ingredients used in the preparation of this supplement are shown in Table 2.

Animals in Treatment 2 (T2) were given straight liquid sugarcane molasses. Intake of molasses was of the order of 0.3 kg head⁻¹ day⁻¹. In addition, cottonseed cake was fed daily at the rate of 0.3 kg head⁻¹ as a protein source. The third group of deer constituted the control (T3). They were given a farm-made supplement commonly known as “melabag”, having ingredients as indicated in Table 3. Melabag was fed daily at the rate of 1 kg per head.

The supplements were given daily on weekdays. A double ration was given on Saturdays, which took care of the Sunday feed allocation.
Table 2  Proportion of ingredients used in the manufacture of CaP4 reconstituted feed supplement

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% by weight (fresh basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane molasses</td>
<td>30</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>15</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>30</td>
</tr>
<tr>
<td>CaP4 Concentrate</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3  Proportion of ingredients used in the preparation of melabag

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% by weight (fresh basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane molasses</td>
<td>31.25</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>6.25</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>12.25</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>32.50</td>
</tr>
<tr>
<td>Maize</td>
<td>15.00</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>1.25</td>
</tr>
<tr>
<td>Common salt</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Animal Health

At weaning, all animals were given an intramuscular preventive shot of 1 ml of Ivermectin to provide protection against internal and external parasites. During the study, 2 animals died: 1 male from Treatment 2 and another male from Treatment 3 due to unknown reasons.

RESULTS

Observations

Pedicle initiation was observed in males by the time they attained a bodyweight of approximately 30 kg, that is, at about 5 months of age. However, spiker stags were sexually active by about 12 months of age.

Body weight

All animals were weighed regularly at monthly intervals, from weaning till the end of study, by means of an electronic balance (accuracy: nearest to 0.1 kg). Animals were mustered and yarded into waiting pens early in the morning and allowed about 2 hours rest to enable them to calm down. Nine weighing sessions were held during the study. The last weights were recorded on 23rd June 1999.

Pasture

Pasture samples were taken from each paddock and analysed for dry matter, crude protein, crude fibre and ash (Table 4). The dry matter content of the young vegetative pasture was unusually high due to the presence of dried stems and leaves.
Evaluation of the performance of deer weaners on three different feed supplements. H.Bheekhe et al.

Table 4  Average chemical composition of fresh *Cynodon plectostachyus* samples at 3 different stages (on dry matter basis)

<table>
<thead>
<tr>
<th>Stage of growth</th>
<th>Dry Matter %</th>
<th>Crude Protein %</th>
<th>Crude Fibre %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young vegetative</td>
<td>44.2 ± 3.6</td>
<td>13.6 ± 2.3</td>
<td>27.1 ± 0.3</td>
<td>7.2 ± 0.3</td>
</tr>
<tr>
<td>Early bloom</td>
<td>37.6 ± 1.3</td>
<td>10.3 ± 0.7</td>
<td>29.8 ± 1.3</td>
<td>8.2 ± 0.1</td>
</tr>
<tr>
<td>Mature</td>
<td>30.5 ± 1.8</td>
<td>7.8 ± 0.7</td>
<td>29.3 ± 1.2</td>
<td>7.0 ± 0.8</td>
</tr>
</tbody>
</table>

Table 5  Average chemical composition of supplements (on fresh matter basis)

<table>
<thead>
<tr>
<th>Feed Supposement</th>
<th>Dry Matter %</th>
<th>Crude Protein %</th>
<th>Crude Fibre %</th>
<th>Ether Extract %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed concentrate</td>
<td>88.2 ± 2.6</td>
<td>19.3 ± 2.8</td>
<td>5.8 ± 5.2</td>
<td>3.2 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>Reconstituted Feed</td>
<td>75.2 ± 2.8</td>
<td>11.4 ± 1.6</td>
<td>10.2 ± 1.9</td>
<td>1.1 ± 0.3</td>
<td>9.2 ± 0.9</td>
</tr>
<tr>
<td>Supplement</td>
<td>79.1 ± 2.5</td>
<td>10.9 ± 0.9</td>
<td>8.2 ± 2.2</td>
<td>1.1 ± 0.2</td>
<td>9.7 ± 1.9</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>74.0 ± 5.7</td>
<td>-</td>
<td>-</td>
<td>7.7 ± 0.6</td>
<td>11.1 ± 0.8</td>
</tr>
<tr>
<td>Molasses</td>
<td>89.3 ± 1.2</td>
<td>38.4 ± 0.9</td>
<td>12.8 ± 1.0</td>
<td>7.7 ± 0.6</td>
<td>7.0 ± 0.1</td>
</tr>
</tbody>
</table>

The calculated mean metabolisable energy (ME) value of CaP4 reconstituted feed supplement, melabag, and molasses + cottonseed cake were 9.3, 10.4 and 11.0 MJ kg⁻¹ of dry feed respectively. That of the forage (*Cynodon plectostachyus*) was 8.5 MJ kg⁻¹ dry matter. The daily ME intakes of the animals supplied by the respective supplements were 6.9 MJ (Reconstituted feed supplement), 8.2 MJ (melabag) and 5.4 MJ (molasses + cottonseed cake). The crude protein contribution of each supplement allocated daily was balanced at 120 g per animal, equivalent to about 67 % of the animal’s daily dietary needs. Pasture fulfilled the balance in their daily nutritional requirements. The overall growth rates of deer from weaning to 9 months post-weaning, at about 13 months of age was calculated (Table 6).

Table 6  Overall growth rates from weaning to breeding/slaughter age (approximately 13 months)

<table>
<thead>
<tr>
<th></th>
<th>Weaning weight kg ± SD</th>
<th>Final weight kg ± SD</th>
<th>Average Daily Gain g ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1 (T1)</td>
<td>25.5 ± 2.5</td>
<td>57.9 ± 6.6</td>
<td>115 ± 21</td>
</tr>
<tr>
<td>Treatment 2 (T2)</td>
<td>25.9 ± 2.4</td>
<td>57.5 ± 6.5</td>
<td>112 ± 19</td>
</tr>
<tr>
<td>Control (T3)</td>
<td>25.8 ± 2.4</td>
<td>58.2 ± 5.0</td>
<td>116 ± 15</td>
</tr>
</tbody>
</table>

The overall differences in mean daily gain in liveweight between the different treatments were not significant.

Figures 1-4 illustrate the pattern of mean liveweight of deer from weaning to 9 months post-weaning. All graphs show that the pattern of growth is almost linear. In Figure 1, the closeness of the graphs indicates that the 3 groups of deer gained weight at approximately the same rate. The same is observed for male deer weaners in all 3 treatments (Figure 2). However, differences are apparent in the growth patterns of female deer weaners, especially as from 3 months post-weaning (Figure 3). Figures 4, 5, and 6 illustrate a general trend whereby males grow slightly faster than females. Liveweight data are presented in Table 7.
Evaluation of the performance of deer weaners on three different feed supplements. H.Bheekhe et al.

Figure 1 Pattern of mean liveweight of deer from weaning to 9 months post-weaning.

Figure 2 Pattern of mean liveweight of male deer weaners from weaning to age at slaughter.

Figure 3 Pattern of mean liveweight of female deer weaners from weaning to breeding age.

Figure 4 Pattern of mean liveweight of male and female deer weaners (Treatment 1).
Evaluation of the performance of deer weaners on three different feed supplements. H.Bheekhie et al.

Figure 5 Pattern of mean liveweight of male and female deer weaners (Treatment 2)

Figure 6 Pattern of mean liveweight of male and female deer weaners (Treatment 3)

Table 7 Growth rates from weaning to breeding/slaughter age on sex basis

<table>
<thead>
<tr>
<th></th>
<th>Weaning weight (kg ± SD)</th>
<th>Final weight (kg ± SD)</th>
<th>Average Daily Gain (g ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Treatment 1</td>
<td>26.2 ± 2.7</td>
<td>24.9 ± 2.3</td>
<td>62.9 ± 5.4</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>26.8 ± 2.4</td>
<td>25.0 ± 2.1</td>
<td>62.2 ± 4.1</td>
</tr>
<tr>
<td>Control T3</td>
<td>26.4 ± 2.6</td>
<td>25.1 ± 2.2</td>
<td>63.4 ± 3.5</td>
</tr>
</tbody>
</table>

Figures with the same superscripts within the same column and those with different superscripts within the same row were significantly different (P<0.05)

In all the treatments, the difference between means was significant for sex, with males gaining weight faster than females during the period of study, that is, up to 13 months of age (P<0.05).

Regression analysis

The pattern of growth of both males and females was similar in all the three treatments. Regression analysis of data obtained show that there is a strong linear relationship with a positive slope between liveweight and age from weaning at 4 months to 13 months old (Table 8) in all the 3 treatments.
Table 8 Regression analysis of growth rates

<table>
<thead>
<tr>
<th>Sex</th>
<th>Relationship</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1 (T1)</td>
<td>Stag: Y = 0.134 X + 25.942</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Hind: Y = 0.100 X + 25.366</td>
<td>1.00</td>
</tr>
<tr>
<td>Treatment 2 (T2)</td>
<td>Stag: Y = 0.133 X + 27.080</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Hind: Y = 0.097 X + 25.428</td>
<td>1.00</td>
</tr>
<tr>
<td>Control (T3)</td>
<td>Stag: Y = 0.134 X + 26.168</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Hind: Y = 0.108 X + 25.080</td>
<td>0.99</td>
</tr>
</tbody>
</table>

The analysis has given rise to linear relationships which can be used to predict the weight of weaners at any age up to 13 months on any of the three supplements studied. These relationships are:

\[
Y = 0.13 X + C \quad \text{males}
\]
\[
Y = 0.10 X + C \quad \text{females}
\]

where,

- \(Y\) = liveweight in kg
- \(X\) = days from weaning
- \(C\) = weaning weight at 4 months

The values of \(R^2\) are >0.99 for all treatments, which strongly support the relationships.

Cost of supplements

The costs of feed supplements were calculated using market price of ingredients at the start of the study. These include transport and labour costs. The calculated costs of supplements used are summarised in Table 9.

One major ingredient used in each of the supplements is sugarcane molasses. Although it is readily available, its market price fluctuates with time. During the course of the study, which lasted for nine months, the price of sugarcane molasses fell from Rs 850 to Rs 300 per tonne. Being a major component in the 3 supplements, a fall in its price resulted in a mean cost reduction of slightly more than 10% of the feed costs indicated above.

Table 9 Costs of supplements fed per animal daily and per kg liveweight gain

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Feed cost head⁻¹ day⁻¹ MUR</th>
<th>Feed cost per kg gain MUR kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaP4 Reconstituted supplement</td>
<td>1.79</td>
<td>15.57</td>
</tr>
<tr>
<td>Molasses + cottonseed cake</td>
<td>2.06</td>
<td>18.30</td>
</tr>
<tr>
<td>Melabag</td>
<td>2.48</td>
<td>21.38</td>
</tr>
</tbody>
</table>

1 US$= MUR30.00

DISCUSSION

The economics of a deer production system imply that it is important for young stags to gain weight as fast as possible to reach early slaughter age. Similarly, hinds should gain weight rapidly to attain breeding weight as early as possible. Appropriate feeding practices are, therefore, necessary to provide the animals with the required nutrients which allow them to grow without any nutritional stress. This study was undertaken to evaluate the effect of feeding 3 supplements to deer weaners, both male and
female, which were reared on open paddocks of size one hectare each. Results show that, irrespective of forage intake, deer weaned at approximately 4 months of age grew fast to target liveweights.

In all treatments, males weaned at about 26 kg at 4 months of age grew at the rate of 128 – 130 g day⁻¹ to exceed a liveweight of 62 kg by the age of 13 months approximately. With an average dressing out percentage of 55%, the hot carcass weight is estimated to be above 34 kg. This is comparable with results obtained in Queensland, Australia where males attained 67.5 kg at 13 months of age, yielding a hot carcass weight of 37.7 kg with a dressing out percentage of 55.2% (Sookhareea, Personal Communication).

In another study in Queensland, Woodford & Dunning (1992) found that stags reared on good irrigated pasture and slaughtered at about 14 months yielded carcass weights ranging from 47 to 50 kg with a dressing percentage of 60%. Unfortunately, deer in Mauritius are farmed on lands that are unsuitable for economic crops such as sugarcane. Higher carcass weights can be expected under improved pasture conditions.

The pattern of liveweight gain as shown in Figures 1-6 confirms findings by Suttie et al. (1992) whereby autumn-born rusa stags showed relatively linear growth from 4 to 19 months of age, whereas spring-born red deer stags reared from 4 to 19 months of age, showed reductions in growth associated with winter and with the rut. Tropical species show less change with season. The pattern of liveweight gain of stags was not similar to that of hinds. In fact, they grew faster than the hinds. This can be explained by the fact that although maintenance requirements are similar between the sexes in young deer, stags require less energy for growth (Suttie et al., 1987). The relationships $y = 0.13x + c$ (males) and $y = 0.10x + c$ (females) described earlier, can be used as a model to predict the performance of deer weaners, data which are essential in farm budgeting.

Regarding reproductive development of deer, puberty in hinds is weight related and rusa hinds become fertile and breed at 45 - 50 kg bodyweight (Lindgren, 1972). In Queensland this weight can be attained as early as 8 months of age on highly improved and irrigated pasture. In this study, all hinds at 13 months of age had attained a liveweight of 52 kg, implying that they were all ready for breeding, having exceeded the critical liveweight requirements (above 45 kg).

Local deer farms rely mostly on supplements for maintenance and growth. Although the final weight of stags at 13 months in all 3 treatments averages around 63 kg, the highest per capita return is expected from Treatment 1, followed by Treatment 2 and the control (Table 10). Feeding molasses in combination with cottonseed cake reduced expenses per head by 2.0% and feeding CaP4 reconstituted supplement by 5.7% over melabag which turned out to be the most expensive supplement. A 1% reduction in expenses incurred during supplementation over a fattening period of 9 months represents savings of MUR 32.50 per head.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Final weight kg</th>
<th>Carcass weight @ 55% DOP kg</th>
<th>Gross return MUR 118 kg⁻¹ kg</th>
<th>Total Cost of supplement MUR</th>
<th>Net Return MUR</th>
<th>% reduction in expenses over T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T 1</td>
<td>62.9</td>
<td>34.60</td>
<td>4,083</td>
<td>571</td>
<td>3,512</td>
<td>5.7</td>
</tr>
<tr>
<td>T 2</td>
<td>62.2</td>
<td>34.21</td>
<td>4,037</td>
<td>648</td>
<td>3,389</td>
<td>2.0</td>
</tr>
<tr>
<td>T 3</td>
<td>63.4</td>
<td>34.87</td>
<td>4,115</td>
<td>791</td>
<td>3,324</td>
<td>-</td>
</tr>
</tbody>
</table>

The actual growth rates of stags achieved with the supplements make it possible to attain an estimated yield of 700 kg ha⁻¹ of carcass meat in a 9-month fattening period (Table 11). A similar yield has been attained by Kelly et al. (1985) whereby yearling red deer stags reared on prime agricultural land produced more than 700 kg carcass weight ha⁻¹ in 170 days in New Zealand.

<table>
<thead>
<tr>
<th>Carcass weight at 13</th>
<th>Net Return head⁻¹ @ MUR 118 kg⁻¹</th>
<th>Estimated carcass wt yld ha⁻¹</th>
<th>Estimated return ha⁻¹</th>
</tr>
</thead>
</table>
Evaluation of the performance of deer weaners on three different feed supplements. H. Bheekhee et al.

Extrapolating from the results obtained, it can be safely deduced that in a fattening unit, at a stocking rate of 20 male weaners hectare\(^{-1}\), deer can be fattened with one of the above supplements to produce 700 kg of carcass meat. The deer farmer has the option to take advantage of the cheapest supplement which produces a feed profit (gross income less feed costs) of Rs 70,240 ha\(^{-1}\). With molasses combined with cottonseed cake the income is estimated at Rs 67,780 ha\(^{-1}\) while with melabag it is Rs 66,480 ha\(^{-1}\).

Regarding growth rates of female weaners, the critical breeding weight which is around 45 – 50 kg bodyweight for yearling rusa hinds (Lindgren, 1972), was achieved in all the treatments. From total cost values of supplements used during the period under study, it is clear that CaP4 reconstituted supplement was the cheapest, followed by molasses + cottonseed cake and melabag (Table 12).

**Table 12** Supplementation cost for hinds

<table>
<thead>
<tr>
<th></th>
<th>Weaning weight kg</th>
<th>Final weight kg</th>
<th>Liveweight change kg</th>
<th>Total cost of supplement head(^{-1}) MUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>24.9</td>
<td>52.9</td>
<td>28.0</td>
<td>436</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>25.0</td>
<td>52.1</td>
<td>27.1</td>
<td>544</td>
</tr>
<tr>
<td>Treatment 3</td>
<td>25.1</td>
<td>54.7</td>
<td>29.6</td>
<td>577</td>
</tr>
</tbody>
</table>

CONCLUSION

This study showed that all 3 feeding regimes used produced results that were comparable in terms of growth rates. At the end of the study, stags were ready for slaughter and hinds for breeding. Stags grew at the rate of 128-130 g and hinds 96-105 g head\(^{-1}\) day\(^{-1}\). However, differences lay in the costs of supplementation. The CaP4 reconstituted feed supplement was the cheapest, followed by the molasses/cottonseed cake combination. Melabag was the most expensive. One advantage, however, of using molasses with cottonseed cake is that this combination needs no prior preparation and is, therefore, fed to the animals straight away. It is apparent that melabag used in the study was a costly supplement. Feed management strategies to maximise deer production on commercial farms should, as far as possible, make use of the most economic feed resources that produce the highest response. Furthermore, this study has generated a relationship which may be useful to predict the production of the farm. The liveweight (\(y\) kg) of growing deer weaners can be estimated by the linear relationships \(y = 0.13x + c\) (stalks) and \(y = 0.10x + c\) (hinds) up to 13 months of age, where \(x\) is the number of days from weaning and \(c\) is the weaning weight at 4 months.

ACKNOWLEDGEMENTS

We would like to acknowledge the assistance of the Manager of Constance Deer Farm to undertake this study and the Principal Research & Development Officer PRDO of the Agricultural Chemistry.
Laboratory, Ministry of Agriculture Natural Resources & Food Technology, for analysis of feed and fodder samples. We also wish to thank RK. Ramnauth, Biometrician, for his helpful suggestions.

REFERENCES


GESTION RAISONNEE DES PATURAGES DANS LES ELEVAGES DE CERVIDES MAURI CIENS

P Grimaud, P Thomas, H Bheekhee et J Sauzier

CIRAD, UAFP, AREU, MDFCS

RESUME

Au sein d'un marché bien organisé à l'île Maurice, la demande en venaison est en constante augmentation. La disponibilité en nouvelles terres étant un facteur limitatif à l'expansion de l'élevage, l'effort doit porter sur l'accroissement de la productivité des exploitations. Celui-ci peut se faire par l'optimisation des pratiques des éleveurs dans la gestion de leurs prairies. Une analyse fonctionnelle des systèmes d'alimentation dans certains des élevages et des chassés de l'île met en évidence qu'une meilleure connaissance des ressources pâturées apporterait à des éleveurs, par ailleurs déjà bien professionnalisés, des critères objectifs de choix dans la gestion de leur système d'exploitation. Les indices de nutrition minérale des fourrages constitutifs des pâturages, évalués à différentes périodes de l'année, sont un indicateur de la fertilité des prairies utilisé à présent en routine dans les exploitations de l'île voisine de la Réunion. La présente étude a pour objectif d'analyser les conditions de reproductibilité d'un suivi identique dans les élevages de cervidés mauriciens, tout en déterminant dans le même temps la valeur nutritive de ces fourrages. Les premiers résultats sur l'état des sols et des pâturages analysés en début de saison sèche montrent qu'une fertilisation plus adaptée permettrait la production d'un fourrage de meilleure qualité.

MOTS CLES : cervidés, île Maurice, gestion prairiale, indices de nutrition minérale, valeur nutritive

INTRODUCTION

La commercialisation de la venaison est principalement assurée sur l'île Maurice par une coopérative d'éleveurs qui, en 1999, a permis l'écoulement sur un marché uniquement local de 2 000 carcasses et 500 animaux vivants à partir d'un cheptel global d'environ 4 500 biches reproductrices. A ce jour, la demande de venaison est en constante augmentation, imposant à la coopérative d'augmenter substantiellement sa production. La disponibilité en nouvelles terres étant un facteur limitatif à l'expansion de l'élevage cervidé sur l'île, l'effort doit porter sur l'augmentation de la productivité des exploitations, et notamment sur l'optimisation de l'utilisation des surfaces fourragères. Sur l'île voisine de la Réunion, un suivi de gestion des prairies, mis en place à la suite du double constat de l'irrégularité de la production de l'herbe et la non durabilité des prairies, est opérationnel dans près de 80 élevages de ruminants. Il se fonde notamment sur le calcul des indices de nutrition minérale du fourrage, témoins de la maîtrise de la fertilisation, et dont l'analyse permet d'optimiser les pratiques de gestion de l'exploitation (Blanfort 1996). La gestion raisonnée des surfaces prairiales cultivées ou non apparaît comme une des clés de la durabilité et de la rentabilité des exploitations dont les surfaces en herbe constituent la ressource fourragère de base. Ce sont les modalités d'application d'une telle étude, étudiées en parallèle avec la détermination de la valeur nutritive des fourrages constitutifs des pâturages, que se propose de décrire cette présentation à partir de visites effectuées dans 10 exploitations, 7 élevages intensifs et 3 chassés.

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 Union des Associations foncières pastorales, Maison de l’Agriculture, PK 23, 97418 Plaine des Cafres, la Réunion
3 The Mauritius Deer Farming Co-operative Society Ltd, 2 Avenue d’Epiney, Quatre Bornes Maurice
MATERIELS ET METHODES

Analyse fonctionnelle des systèmes d'alimentation

La description du fonctionnement des systèmes d'alimentation s'est faite par une enquête auprès de chacun des éleveurs sur leurs pratiques en matière de conduite au pâturage et de complémentation, selon une méthodologie calquée sur celle développée en France par l'Institut de l'Elevage (Moulin 1998).

Estimation de la biomasse et des indices de nutrition minérale des fourrages

La biomasse des surfaces prairiales est mesurée par plusieurs lancers d'un carreau de 50 cm de côté délimitant une surface où est prélevé l'ensemble du fourrage coupé à une hauteur de 5 cm. Cette mesure a été effectuée en juin 2000 dans les 10 exploitations réparties en différents points géographiques de l'île, dans plusieurs parcelles sélectionnées par les éleveurs. Au total, 40 échantillons de fourrage ont été collectés. Les indices de nutrition minérale de la plante sont issus de la détermination au laboratoire de l'Université des teneurs en phosphore, azote et potassium des échantillons collectés à l'occasion de ces déterminations de biomasse ; ils sont le résultat de formules élaborées par les chercheurs de l'INRA à partir des lois de dilution de ces éléments, validées à l'île de la Réunion par Blanfort (1996).

Analyse de la valeur nutritive

Pour chacun des mêmes échantillons de fourrage, un passage au laboratoire de l'Université a permis la détermination des taux de matière sèche, de matière organique, de matières azotées et de cellulose brute. De ces différentes analyses ont été déduites les valeurs des fourrages en digestibilité de la matière organique (dMO), en unités fourragères (UF) et en protéines digestibles au niveau de l' intestin grêle (PDI), selon les équations de détermination de l'INRA (1982) adaptées aux fourrages tropicaux (Brégeat et al. 1994). La valeur en matières azotées digestibles (MAD) est déduite de la matière azotée totale selon l'équation de Chenost (1975), reprise par Aumont et al. (1991).

RESULTATS ET DISCUSSION

Analyse fonctionnelle des systèmes d'alimentation

Les éleveurs évoluent avec un minimum de 2 troupeaux tout au long de l'année, l'un de reproducteurs et le second d'abattage, constitué à la période du sevrage des jeunes. Néanmoins, certains d'entre eux gèrent jusqu'à 6 troupeaux sur l'année. Tous pratiquent le pâturage tournant : pour le troupeau de reproducteurs jusqu'aux premières mises-bas, période à partir de laquelle les femelles retrouvent les prairies qui leur sont régulièrement affectées : il sera alors procédé à l'ouverture progressive de ces parcelles tout au long de la période des naissances sans fermer les parcelles précédentes, en raison du comportement nidicole du faon nouveau-né. C'est à l'issue de cette période que la gestion du parcellaire est la plus complexe, car c'est l'époque de l'année où l'herbe est la moins disponible. La conduite du troupeau d'abattage est plus simple : les rotations se font toute l'année, le rythme de rotation différent selon la saison étant plus rapide en saison sèche. La période d'abattage a lieu d'octobre à mai. Dans les chassés, où l'exploitation des animaux ne se fait a contrario que de juin à septembre, les animaux ne forment généralement qu'un troupeau : les mâles s'isolent de décembre, au moment de la chute des bois, à juin, où ils rejoignent les femelles. La majorité des pâturages des élevages intensifs sont à base de "sikin" ; sous cette dénomination on trouve plusieurs graminées, essentiellement Bothriochloa pertusa et Themeda triandra. Pérennes et stolonifères, très appétantes, elles résistent à la fois au surpâturage et à la sécheresse et leur gestion est donc peu exigeante. Dans 6 des 7 exploitations enquêtées, le star grass (Cynodon plectostachium) a été implanté par bouturage pour améliorer les pâturages. Forte colonisatrice, cette graminée répond bien lors de son implantation à la fertilisation, souvent réalisée avec de la litière de volaille. Sa pousse reprend dès les premières pluies et se poursuit au moins jusqu'en avril. Dans les chassés, les surfaces sont plus grandes et recouvertes en majorité de forêts. La proportion de plaines est variable, de 15 à 33...
% des surfaces, et dans l’intérieur des terres plus en altitude, l’herbe d’argent (Ischaemum aristatum), pérenne et stolonifère, y prédomine. Des enquêtes auprès des éleveurs il apparaît que la période la plus critique en matière de pâturage va de la deuxième moitié de la saison sèche hivernale jusqu’aux premières pluies, soit pratiquement de la fin août jusqu’au mois de décembre. Dans tous les élevages, il est fait une large part aux ligneux dans la disponibilité fourragère des animaux en saison sèche. Les espèces les plus fréquentes sont le bois d’oïseau (Litsea glutinosa), le bois noir (Albizia lebbeck), le campèche (Haematoxylum campechianum) et l’acacia (Leucaena leucocephala). Mais c’est également sur la complémentation alimentaire que s’appuient les éleveurs pour conserver à leurs animaux un état corporel satisfaisant. Les femelles reproductrices en reçoivent de la mi-juin aux premières pluies, arrêtant d’elles mêmes sa consommation quand le pâturage a repris. La complémentation du troupeau d’abattage est la plus forte en hiver, période de pénurie fourragère, mais également de mars à mai, où la coopérative éprouve des difficultés à se procurer des animaux de bonne conformation. Le plus fréquemment, l’aliment proposé répond à l’appellation de "mélabag", du fait de sa composition à base de résidus de l’industrie sucrière. Toutefois, les proportions de mélasse et de bagasse dans le produit distribué aux animaux sont variables selon les exploitants, qui les associent parfois à d’autres matières premières, comme le son de blé, à des éléments minéraux ou à des aliments du commerce.

**Biomasses et indices de nutrition minérale**

Les rendements moyens des parcelles étudiées apparaissent dans le Tableau 1. La production en matière sèche du sikin est deux fois plus faible que celle des deux autres graminées, dont la biomasse à l’approche de la saison sèche reflète le bon potentiel fourrager des pâturages. Le sikin est également celui des 3 fourrages dont le pourcentage de matière sèche est le plus élevé : 49 %, vs. 36 % pour le star grass et 23 % pour l’herbe d’argent. Ce fort taux de matière sèche confère à ce fourrage un aspect pailleux qui reste cependant consommable. En Nouvelle-Calédonie où B. pertusa est très commun dans les plaines et sur les collines de la côte Ouest aux conditions climatiques proches de celles rencontrées au sud ouest de l’ile Maurice où il prédomine, un pâturage de sikin au rendement annuel moyen de 1,9 t MS ha⁻¹ permet l'entretien de 4,3 unités "stock unit" de cervidés (Brégeat et al. 1994). Quelle que soit la nature du pâturage, ces taux de matière sèche néanmoins élevés peuvent être le témoin d’une consommation du fourrage à des stades largement dépassés ne permettant pas l’obtention d’un meilleur compromis entre la qualité et la quantité des prairies mises à disposition des troupeaux. Les valeurs des indices de nutrition minérale des fourrages sont également présentées Tableau 1. Elles montrent globalement un déficit par rapport aux références souhaitables (proches de la valeur 100) en azote et en phosphore pour les 3 fourrages étudiés, alors que les indices de nutrition en potassium mettent en évidence une consommation de luxe en cet élément. La faiblesse des valeurs IN est surtout visible pour le sikin, montrant que ce fourrage ne peut satisfaire la demande en azote des animaux. Les parcelles implantées en star grass et en herbe d’argent présentent des indices supérieurs, vraisemblablement dus à une fertilisation azotée préférentiellement dirigée vers ces fourrages. Le déficit en phosphore est commun à tous les pâturages. De tels résultats signent un déséquilibre nutritionnel très marqué entre ces 3 éléments minéraux, qui nécessite un réajustement impératif quant au choix des formules d’engrais minéraux à apporter aux pâturages et vraisemblablement également quant aux doses et aux dates de ces épandages.

**Valeur nutritive**

Les valeurs de la digestibilité de la matière organique des fourrages analysés sont très faibles, aucune d’entre elles n’atteignant un pourcentage supérieur à 50 % (Tableau 1). Les valeurs en unités fourragères qui en découlent sont peu élevées, d’environ 25 % inférieures à celles référencées pour des graminées des mêmes genres en Nouvelle-Calédonie (Brégeat et al. 1992) ou en zone Caraïbe (Aumont et al. 1991). Cette faiblesse des valeurs en unités fourragères (UF), fréquente pour les fourrages tropicaux, est exacerbée par une exploitation trop tardive de ces fourrages : certains fourrages présentent des taux de cellulose brute supérieurs à 600 g par kg de matière sèche, avec des valeurs en matières azotées totales inférieures à 50 g kg⁻¹ MS. Ces résultats, obtenus d’équations prédictives à partir des valeurs bromatologiques obtenues en laboratoire, devront être cependant confirmés par d’autres méthodes en cours de détermination de la digestibilité : la dégradabilité de la matière sèche par des mesures in vivo dans la station expérimentale de l’AREU et la détermination de la digestibilité enzymatique selon la méthode de Aufrère et

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1 Stock Unit : unité théorique correspondant à une brebis standard de 55 kg allaitant 1,1 agneau

Demarquilly (1989) sur une dizaine d’échantillons (un par exploitation) nous permettront d’affiner cette valeur de digestibilité. Les valeurs protéiques (MAD et PDI) sont en revanche plus proches des valeurs tabulaires de ces zones tropicales.

**Tableau 1** Moyennes, écarts-types, et valeurs maximales et minimales du rendement (t MS ha⁻¹), des indices de nutrition minérale et de la valeur nutritive des fourrages dominants dans les pâturages

<table>
<thead>
<tr>
<th>n</th>
<th>Rendement DMO</th>
<th>IN</th>
<th>IP</th>
<th>IK</th>
<th>%</th>
<th>PDIN</th>
<th>PDIE</th>
<th>MAD</th>
<th>UFL</th>
<th>UFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS t ha⁻¹</td>
<td>MS g kg⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star grass <em>Cynodon plectostachium</em></td>
<td>17</td>
<td>3.9 ± 1.8</td>
<td>77 ± 15</td>
<td>43 ± 10</td>
<td>143 ± 26</td>
<td>38 ± 8</td>
<td>54 ± 20</td>
<td>65 ± 15</td>
<td>50 ± 29</td>
<td>0.42 ± 0.10</td>
</tr>
<tr>
<td>1.5 - 9.0</td>
<td>43 - 106</td>
<td>23 - 58</td>
<td>79 - 193</td>
<td>17 - 49</td>
<td>29 - 94</td>
<td>32 - 87</td>
<td>13 - 108</td>
<td>0.16 - 0.57</td>
<td>0.08 - 0.47</td>
<td></td>
</tr>
<tr>
<td>Sikin <em>Bothriochloa pertusa</em></td>
<td>10</td>
<td>1.7 ± 0.7</td>
<td>38 ± 14</td>
<td>46 ± 15</td>
<td>154 ± 56</td>
<td>30 ± 8</td>
<td>36 ± 5</td>
<td>50 ± 13</td>
<td>23 ± 7</td>
<td>0.31 ± 0.10</td>
</tr>
<tr>
<td>0.5 - 2.6</td>
<td>22 - 56</td>
<td>21 - 67</td>
<td>80 - 260</td>
<td>11 - 37</td>
<td>31 - 45</td>
<td>19 - 61</td>
<td>16 - 37</td>
<td>0.10 - 0.41</td>
<td>0.03 - 0.30</td>
<td></td>
</tr>
<tr>
<td>Herbe d’argent <em>Ischaemum aristatum</em></td>
<td>9</td>
<td>3.4 ± 1.0</td>
<td>66 ± 6</td>
<td>31 ± 11</td>
<td>117 ± 32</td>
<td>36 ± 3</td>
<td>42 ± 11</td>
<td>60 ± 7</td>
<td>32 ± 15</td>
<td>0.39 ± 0.04</td>
</tr>
<tr>
<td>2.3 - 4.9</td>
<td>58 - 73</td>
<td>13 - 50</td>
<td>63 - 187</td>
<td>30 - 40</td>
<td>25 - 57</td>
<td>48 - 70</td>
<td>8 - 53</td>
<td>0.31 - 0.43</td>
<td>0.20 - 0.32</td>
<td></td>
</tr>
</tbody>
</table>

La faiblesse des indices de nutrition en phosphore doit nous interpeller sur les carences minérales des prairies mauriciennes, et par conséquent sur la non satisfaction des besoins des animaux qui ne sont pas complémentés toute l’année. Pour diverses raisons, essentiellement budgétaires, des analyses minérales en calcium n’ont pas pu être associées aux déterminations précédentes. De nombreuses données sur les teneurs en minéraux des graminées tropicales sont disponibles, mais elles ne sont véritablement indicatives que pour les terrains où elles ont été échantillonnées. Une analyse fonctionnelle des prairies mauriciennes peut à ce titre être envisagée.

**CONCLUSION**

L’étude de l’analyse fonctionnelle des systèmes d’alimentation dans les élevages de cervidés mauriciens montre que les éleveurs exploitent leurs animaux et leurs prairies de façon rationnelle. Leur gestion repose sur la double volonté de maintenir un état de l’entretien de l’animal satisfaisant tout en protégeant une flore des prairies suffisamment abondante pour la satisfaction du besoin des animaux une large partie de l’année. L’étude ponctuelle sur les indices de nutrition minérale des fourrages et leur valeur nutritive met cependant en évidence la possibilité d’améliorer leurs pratiques en fonction de différents critères, comme la fertilisation des parcelles ou leur utilisation à des stades de repousse de l’herbe optimisant sa valeur nutritive. La mise en place d’un suivi de gestion raisonnée des pâturages, proche de celui initié depuis plusieurs années dans les élevages de ruminants de l’Île voisine de la Réunion, permettrait de mieux appréhender l’impact de l’évolution de ces pratiques. Des analyses complémentaires sont en cours, sur les fourrages mais également sur les sols, dont les résultats seront utilisés pour l’élaboration d’un calendrier de suivi satisfaisant à la fois les éleveurs et les organismes qui peuvent les appuyer.
REMERCIEMENTS

Les auteurs remercient l'ensemble des éleveurs pour leur appui, le Docteur Driver et son équipe au laboratoire d'analyse de l'Université, et les organismes qui ont participé financièrement à cette étude (Economic and Marketing Management et Mauritius Meat Producer's Association).

REFERENCES


ISOLATION AND IDENTIFICATION OF INFECTIOUS BURSAL DISEASE VIRUS IN CELL CULTURE FROM CLINICAL CASES

RN Srivastava, D Sibartie, MR Jaumally, R Ramjee and A Arlandoo

Ministry of Agriculture, Food Technology & Natural Resources

ABSTRACT

The infectious bursal disease virus was isolated in chicken embryofibroblast cell-culture (CEF) from bursal suspension of suspected dead chicks. The viral isolate was well adopted and titrated at sixteenth passage level in CEF. The serum neutralisation test in cell-culture and enzyme linked immunosorbant assay revealed that the isolate is of classical IBD serotype I. The morphology of IBD virus was also seen in electron microscopy of infected cell-suspensions. The details of the results are discussed.

key words::Cell-culture, IBDV, Serum-neutralisation, ELISA, serology, Electron microscopy, Isolation of virus.

INTRODUCTION

Infectious bursal disease (IBD) is a highly contagious acute viral infection of young chickens. The mortality in chicks aged between 3 weeks and 8 weeks may range from 20% to 90% depending upon the virulence of the infecting strain. The main target organ is the \textit{bursa fabricius} of the chicken which led to severe immuno-suppressive conditions in young chicks. The disease is ubiquitous in nature having spread all over the world. The infected chicks show depression, ruffled feathers, anorexia, diarrhoea, trembling and dehydration. \textit{Bursa fabricius} and kidney are enlarged, necrotic and badly damaged. The disease is widely spread in Mauritius inspite of the regular vaccination. The average mortality due to IBD is 20% to 30% in vaccinated flocks of the island. The annual loss to this country due to IBD alone is of the order of Mauritian rupees 70 million (Sibartie et al,2000). The Division of Veterinary Services is envisaging to develop a tissue-culture vaccine of IBD from local viral isolate to contain the disease and consequent mortality. In the present study the isolation and identification of local strains of IBD was attempted in order to produce a protective and innocuous tissue-culture based attenuated vaccine.

MATERIALS AND METHODS

Virus isolation in cell culture

Cell Culture

Chicken fibroblast cell-culture was grown using tissue-culture media (sigma, USA) in bottles. The 9 days old embryonated eggs were procured form Government Poultry Farm, Reduit. The embryo were aseptically separated out from eggs, washed, and eyeballs, legs, beaks and feathers were removed. The rest of the body portion was further washed, cut into small pieces and trypsinised with 0.25% Trypsin solution in PBS for half an hour. The cell suspension was filtered and cells were washed three times by refrigerated centrifugation. The cell sediment was mixed with growth media to get $10^6$ cells/ml and the same was dispensed in bottles. The monolayer was ready in 24 hours.
Infection of Cell-culture

The 10% suspension was made of bursa fabricius in PBS which was centrifuged at 4000 rpm for 30 mts at 4°C and the supernatant was passed through 0.45 pore size membrane filter. The CEF was infected with 0.5 ml of filtrate. The virus was allowed to adsorb on the cell receptor for one hour at 37 °C. Afterwards the infective material was decanted, the cells were washed and maintenance medium was added in bottles which were replaced in the incubator. The cells were looked for cytopathic changes, if any, after 24 hours post infection for 3 – 4 days. The viral isolate was given up to 16th passage in CEF cell culture.

Titration of the virus

The viral isolate at 16th passage level was titrated in CEF cells on microtitre plate. Ninety microlitres (90 µl) of media were dispensed in three rows (A,B,C) from well No. 1 to 12 of the plate. Afterwards 10 µl of virus was added in the 1st well of all the three rows (A,B,C). Virus was thoroughly mixed in the 1st well and 10 µl were transferred from 1st well to 2nd well and onwards till 11th well to make ten fold serial dilutions of the virus. The 10 µl from 11th well was discarded. The 12th well of all the three rows was kept as cell control. Simultaneously virus control was also kept in other wells. Henceforth, 100 µl of CEF cells at a concentration of 1 x 10^6 cells/ml was added in all the wells of the three rows. The plate was properly sealed and incubated at 37°C. Development of cytopathic effects was observed in each well after every 24 hours interval for four days. The reading of CPE was recorded as soon as the CPE was complete in virus control. The titre was calculated as per the method of Reed & Muench (1938).

Serological tests

Serum Neutralisation Test

This test was performed using constant virus and varying dilution of serotype specific antisera (serotype I and serotype II). Serotype specific antisera were procured from Ohio Agricultural & Development Centre; the Ohio States university, Ohio, USA by courtesy of Dr. Y.M. Saif. Two fold serial dilution was made in microtitre plates for both the serotype specific sera separately starting from 1:10 and so on with the help of multichannel pipette in 50 µl amounts. Serum dilution was made in three rows of 12 wells each for serum of serotype I and another set of three rows for serum of serotype II. In the first column 90 µl of media was added while in the rest of the wells 50 µl of media was added. Ten µl of serotype I antisera was added in three wells of the first column; similarly 10 µl of serotype II was added in the 1st column of another set of three wells. After thorough mixing, 50 µl of sera was taken from 1st column to 2nd column and so on till 12th column with the help of multichannel pipette. The 50 µl mixed sera from 12 column was discarded to make two fold dilution in 50 µl amounts, beginning 1:10 dilution for both serotype specific sera. Fifty micro litre (50 µl) of IBD2(16) virus containing 100 TCID 50 was added in each well of the plate. Simultaneously sera, virus and cell control were also kept in the plate. The plate was sealed and the serum – virus mixture was incubated for 1 hour at 37°C in moist chamber. Afterwards 100 µl of cell suspension containing 1 x 10^6 cells ml^-1 was added to all the wells. Plate was again sealed and incubated at 37°C to observe the development of CPE in each well every 24 hours.

Enzyme-linked immunosorobent assay

Preparation of antigen and coating of Elisa plates

The IBD2(16) passage virus was concentrated five fold from the original volume with the help of dylisis against PEG-6000. The concentrated virus was further sonicated to release the cell-associated viral particles. The sonicated virus was then centrifuged at 8 000 rpm for 20 minutes. The supernatant was collected and diluted with coating buffer. The Elisa plate was coated with 50 µl of antigen and the plate was incubated at 37°C for two hours followed by keeping the plate overnight at 4°C in the refrigerator. Afterwards the antigen from coated plates was discarded and each well was thoroughly washed three times with washing (PBS-Tween) buffer.
Test paper

Serial two fold dilution was made of both serotype I and serotype II specific antisera separately. Fifty microliters (50 µl) of each dilution was added in duplicates in antigen coated wells of the ELISA plate. Simultaneously negative and positive sera control were also kept on the plate. The plate was incubated at 37°C for an hour followed by three rigorous washings by PBS-Tween buffer with the help of Auto mini washer. Afterwards, 100 µl of antichicken, IgG horse radish peroxidase was added to each well and again incubated at 37°C for one hour. The washing procedure was repeated again three times so that no fluid be left in the wells. Thereafter, 100 µl of substrate (ABTS) solution was added to each well for incubation at room temperature to allow the development of colour. The moment colour started developing, after 10 minutes, 50 µl of stop solution was added and the optical density (O.D) value of the colour was recorded at 450 nm wave length on a MTR-120 microplate reader. The corrected O.D value of each serum sample was calculated by subtracting the negative serum O.D value from the O.D value of the rest of the wells. A corrected O.D value of more than 0.2 was considered positive.

Electron microscopy

The viral isolates in CEF was sent to Dr. R.E. Gouch of Veterinary Laboratories Agency, Surrey, United Kingdom for electron microscopy to see the morphology of Birna virus. The negative staining was done to see the virus if any, under the electron microscope.

RESULTS

Cytopathic changes in infected cell-culture

The confluent monolayer of CEF was ready in 24 hours post seeding of cells. The cells were infected by bursal suspension and in first passage, the rounding of the cells were seen in 72 to 96 hours post infection. However, the CPE could be seen after 24 hours post infection as soon as the virus got adopted by CEF cells. The viral isolate was given up to 16th passage IBD2(16) in cell-culture. Rounding of the cells started 24 hours post infection followed by clumping, syncytial formation, vacuolation and finally the cells started detaching from the surface of the bottles (Plates 1,2,3). The viral isolate is well adopted by the CEF cells.

Plate 1 Healthy uninfected CEF cells 72 hrs post incubation
Isolation and identification of infectious bursal disease virus in cell culture from clinical cases  RN Srivastava et al.

Plate 2  Cells showing CPE characterised by rounding of cells 48 hrs post infection

Plate 3  Cells showing CPE characterised by rounding, granulation and vacuolation of cells 72 hrs post infection

Titration of the virus

The titre of the virus at level of 16th passage IBD2(16) in CEF was recorded as $4.375 \log_{10} \text{TCID} 50/10 \log_{10} \text{TCID} 50/\mu l$ based on more than 50% cytopathic effect in cell culture. The titre was further calculated as $7.37 \log_{10} \text{TCID} 50/\text{ml}$ of the isolate.

Serum neutralisation test

The serum neutralisation test was performed for serotyping of our viral isolate IBD2(16). It was recorded that the serotype I specific antisera could neutralize at 1:320 dilution while serotype specific II sera could neutralise the same amount of virus at 1:10 dilution (Table 1). It revealed that our viral isolate is serotype I as serotype I specific sera is neutralizing the virus in higher dilution compared to serotype II sera. The serum neutralization titre of serotype I was calculated as $5.579 \log_{10} \text{ml}^{-1}$ while it was $4.15 \log_{10} \text{ml}^{-1}$ for serotype II. Hence the neutralization index of serotype I was greater than serotype II by $1.429 \log_{10} \text{ml}^{-1}$. 

AMAS 2001. Food and Agricultural Research Council, Réduit, Mauritius. 198
Elisa test

ELISA plate was coated with our viral isolates. Both serotype I and II specific sera showed positive reaction with our IBD2(16) virus and the intensity of the colour decreased as the dilution of antisera increased. However, it was recorded that serotype I specific serum could show positive reaction at a dilution of 1:640, while serotype 2 only showed reaction at a dilution of 1:80 (Figure 1). In addition the colour intensity as per O.D value was greater with serotype I serum compared to serotype II serum. It further confirmed that our viral isolate IBD2(16) is infectious bursal disease virus and of serotype I.

Table 1 Serum neutralisation test with IBD (16) virus

<table>
<thead>
<tr>
<th>Serotype Specific Antisera</th>
<th>Dilution of serotype specific antisera</th>
<th>Titre in Log 10 ml⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:10</td>
<td>1:20</td>
</tr>
<tr>
<td>Serotype I</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Serotype II</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Reference –ve sera control</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*+= Virus neutralised, denoting suppression of 80 to 100 percent CPE

- = Virus not neutralised, denoting 80 to 100 percent CPE

Electron microscopy

The IBD viruses are classical birna group of viruses having icosahedron symmetry with no envelope. The size of the virus is 60 nm in diameter having bisegmented DS RNA genome. The electron micrograph of viral isolate (Plates 4 & 5) are depicting the classical morphology of birna group of viruses.

DISCUSSION

Infectious bursal disease in young chicken has become endemic both in Mauritius and Rodrigues. Mortality in chicks is alarming even in vaccinated birds. Vaccines being used in Mauritius are imported and are not providing complete protection. It was realised that either the vaccine being used is not properly attenuated for the birds or some different local strains, other than the vaccine strain are responsible for the heavy toll in birds.
In order to isolate the local strain, the bursa was collected from the chicks dying of classical IBD syndrome and the virus was attempted to grow in chicken fibroblast cells culture. The virus was well adopted and cytopathic effect was seen in 24 hours post infection (Plates 1, 2 & 3). Identification of the virus was further done employing different serological tests. Serum neutralization and ELISA test with reference IBD sera revealed that the viral isolate is nothing but IBD virus. Serotyping of the viral isolate was also done with the help of serum neutralization test using serotype specific antisera. Only two known and well-established serotypes of IBD virus are present all over the world.

**Plate 4** Morphology of virus particles seen under electron microscope 38 000 X

![Plate 4](image4)

**Plate 5** Showing Icosahedron symmetry of classical Birna virus 38 000 X

![Plate 5](image5)

The result of serum neutralization revealed that the local viral isolate belongs to serotype I. The virus neutralization test is the only serological test that will detect the different serotypes of IBDV and it is a method of choice to discern antigenic variations between isolates of the virus (Jackwood and Saif, 1987). The viral isolate has been sent to some foreign laboratory for strain identification. Since only serotype I virus in chicken results in clinical sign (Lasher and Shane, 1994), it has become now imperative to know the precise strain of viral isolate to venture for vaccine production. Although ELISA test is generally not recommended and used for serotyping of IBDV, this test also gave an indication that the viral isolate was serotype I as evident from Plates 1 to 3. ELISA test was positive only between dilutions of 1:80 and 1:160 of serotype II specific serum, while serotype I serum gave positive results even at 1:640 dilution. Both serum neutralization and ELISA are highly specific and sensitive serological tests for characterization of viruses. Electron microscopy depicted the classical morphology of Birna viruses in our viral isolate. The production of tissue culture based attenuated vaccine is already in progress in the virology section of the division of veterinary services animal health laboratory, Ministry of Agriculture.
CONCLUSION

The virus from local chicks dying of IBD syndrome was isolated in CEF and identified by serological characterization and electron microscopy. The viral isolate was found to be serotype I specific IBD virus. Further characterization at genetic level and production of vaccine is in progress.

ACKNOWLEDGMENTS

We wish to place on record our sincere thanks to Dr. Y.M. Saif for the supply of serotype specific antisera and also to Dr. R.E. Gouch for sero-pathotyping and electron microscopy of our viral isolates. Help of the typists namely Mrs. S. Senedhun, Mrs. A. Heeroo and Mrs. P. Bappoo is also thankfully acknowledged.

REFERENCES


VER A SOIE ET POISSON

Odette Ralambomanana

FOFIFA

RESUME

Les qualités des eaux sont favorables à la pisciculture. L’apport de fumure organique implique la prolifération des nourritures naturelles: phyto-zoo-plancton, larves d’insectes aquatiques, font la moitié de la nourriture des poissons. La chrysalide de ver à soie est riche en protéines, en graisses et en vitamines: mélangé avec du son de riz, c'est une bonne nourriture en matière de pisciculture.

Les élevages ont duré 96 jours pendant deux campagnes: 1993-1994; 1994-1995. Régulièrement la production piscicole obtenue (taille, poids) varie d’une concentration en chrysalide à une autre. La meilleure production est obtenue pour une concentration de 25%. Les résultats sont les mêmes pour une teneur à 30%. Ainsi, on a arrêté le mélange à 25%. La croissance des poissons dépend de la nourriture consommée entre autres facteurs (qualité de l’eau, génétique etc.…)

Les taux de survie sont élevés puisque les poissons sont régulièrement nourris, et ils sont protégés contre les prédateurs.

Mots clés: chrysalide, nourriture, poissons, croissance, taux de survie, eau, élevage.

INTRODUCTION

Les rizières irriguées sont exploitées pour pratiquer la pisciculture, pour rentabiliser les matières organiques produites. L’intensification de la production piscicole est l’effet de la nourriture, et est directement influencée par la quantité de nourriture naturelle disponible dans le milieu. Cela s’obtient par de l’apport de fumure organique dans les eaux des rizières, les multiples interventions et aménagements.


Les qualités des eaux de ces rizières, sont données par les analyses faites mensuellement. Elles emmagasinent les éléments nutritifs. Les analyses qualitatives et quantitatives de la biocénose, reflètent leur évolution, dont les éléments servent de nourritures aux poissons.

APPROCHE EXPERIMENTALES - MATERIELS ET METHODES

Trois types d’expérience ont été réalisés sur:

1. La qualité physico-chimique des eaux dont les objectifs ont été de mettre en évidence l’évolution de la qualité des eaux en fonction des apports extérieurs et des reliquats de provende devenus apports soutenus de fumure riche en protéines et phosphates.
2. La production de nourritures naturelles relativement à la fertilisation des eaux.
3. Le nourrissage et la croissance des poissons avec de la provende de chrysalide.
Tableau 1 Analyses bromatologiques de la chrysalide de ver à soie *.

<table>
<thead>
<tr>
<th></th>
<th>% produit brut</th>
<th>% produit sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teneur en eau</td>
<td>11.9</td>
<td>-</td>
</tr>
<tr>
<td>Matière sèche</td>
<td>88.1</td>
<td>-</td>
</tr>
<tr>
<td>Cendres brutes</td>
<td>5.5</td>
<td>6.2</td>
</tr>
<tr>
<td>Matières grasses brutes</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Protéines brutes</td>
<td>69.5</td>
<td>78.9</td>
</tr>
<tr>
<td>Celluloses brutes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.42</td>
<td>0.48</td>
</tr>
<tr>
<td>Phosphore total</td>
<td>1.08</td>
<td>1.23</td>
</tr>
<tr>
<td>Cendres insolubles dans HCl</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Analyses effectuées au Ministère des recherches scientifiques: Département des Recherches Zootechniques et Vétérinaires, Division alimentation animale, Laboratoire de chimie.

Matériel domanial

Les rizières ont été choisies de façon à ce que les dimensions ne soient pas trop différentes: 1.33 – 1.68 ares. Les expérimentations ont duré deux campagnes agricoles.

Ces rizières ont été séchées et couvertes de fumure organique du mois de septembre à la première quinzaine d’octobre. On procède au labour avec une charriere vers la deuxième quinzaine d’octobre. La fumure organique est retournée avec la motte de terre. L’irrigation commence la deuxième quinzaine du mois de novembre. Le piétinage est fait avec une herse suivi de l’aplanissement. Le repiquage manuel en ligne se fait après élimination des saletés (herbes sèches trop dures par exemple). Il n’y a qu’une lame d’eau dans la rizière et petit à petit on augmente le niveau. Un mois après le repiquage les plantes reprennent; la hauteur d’eau atteint 20 cm ou plus. C’est là qu’on fait le déversement.

On a employé le dispositif en bloc complet: trois blocs et cinq traitements: 0, 7.5, 15, 25, et 30%. C’est le pourcentage de farine de chrysalide incorporée dans la provende. 0% est donc le témoin. La répétition est faite au hasard. On utilise les mêmes rizières pour les mêmes traitements pendant les deux campagnes.

Matériel animal

Les poissons élevés ont été achetés chez les paysans producteurs d’alevins: *Cyprinus carpio*. C’est l’espèce la plus cotée dans la région. Le déversement se fait tôt le matin pour éviter le choc thermique, ou écologique. L’eau du récipient de transport est mélangée avec celle de la rizière à empoissonner. Cette opération se fait à 2 ou 3 reprises et on déverse après. On procède au pesage et mensuration avant le déversement. Il n’y a pas de mortalité puisque le transport ne dépasse pas 3 - 4 km. La capacité biogénétique des rizières étant moyenne, on a fixé la densité à 40 individus à l’are.

Les poissons ont été nourris deux fois par jour avec de la provende de chrysalide, pour 5 % de la biomasse dont 2.5 % est donné le matin vers neuf heures et 2.5 % distribué l’après-midi vers 15 heures. La nourriture naturelle doit constituer une part importante de l’alimentation de ces poissons. Balvay en 1980 propose que le déversement se fasse au moment de la biocénose.

Echantillonnages, analyses et mesures

Les variables qui touchent de près la vie piscicole sont analysées deux fois pendant la campagne avant le déversement (décembre) et pendant l’élavage. Cela indique les corrections à apporter et ou les lacunes à combler pour aboutir à l’intensification de la production piscicole. Ces paramètres sont: température, oxygènes dissous, pH, calcium, magnésium, gaz carbonique, azote ammoniacal et nitreux, phosphate silicate.

* La fumure organique est une bouse de vache fermentée deux mois avec de la paille de riz ou de l’herbe sèche. C’est le fertilisant couramment utilisé dans la région.

On prend un litre d’eau de chaque rizières avec un flacon débouché et rebouché après prise à même l’eau, pour empêcher l’entrée d’oxygène de l’air d’y entrer. L’analyse est effectuée tout de suite avec la méthode colorimétrique en utilisant les produits merck. On contrôle par échantillonnage bimensuel, la production de nourriture naturelle, plancton et benthos.

**Plancton**

On prend 50 litres d’eau dans chaque rizières qu’on verse dans un filet à plancton de 50µ de vide de maille. L’échantillon est recueilli dans un pilulier et est fixé avec du formol 5%. On mesure le bio volume du plancton au laboratoire avec un cône de sédimentation.

**Benthos**

1dm³ de vase dans chaque rizières est pris avec une boîte. L’échantillon est tamisé. Les organismes du benthos sont triés, mis dans des piluliers, fixés avec du formol 5%. La détermination des éléments planctoniques et benthiques se fait avec une loupe et un microscope binoculaire marque Kraus et Leitz Wetzellar.

**Production piscicole**


**RESULTATS ET DISCUSSIONS**

**Qualités physico-chimiques des eaux**

Les résultats sont consignés dans le Tableau 1.

**Température**

La température est favorable à la vie piscicole pendant l’expérimentation (deux campagnes) 24.9°C <t < 28°C puisque Schaperclaus en 1982 dit que cette espèce voit sa croissance dans l’eau chaude, son optimum de développement correspond à 20°C et 25°C. On est dans la plage requise durant les essais.

**pH**

Durant l’expérimentation la valeur du pH est de 6.6 – 7.2, légèrement acide. C’est tangent pour la carpiculture puisque la valeur comprise entre 6.5 et 8.5 est nécessaire d’après Arrignon en 1976.

**Oxygène dissous**

Les teneurs en oxygènes dissous sont élevées 10.8 – 11.2 mg/l; c’est à cause de l’activité photosynthétique des plantes de riz. Bremond et Perrodom en 1979 indiquent que la dose minimum est de 5 mg/l pour qu’il n’y ait pas suffocation des poissons. La teneur en oxygène dissous est suffisante

**Gaz carbonique**

L’eau est pauvre en gaz carbonique: 2 – 18.7 mg/l. C’est toujours à cause de l’activité photosynthétique, puisqu’on a effectué le prélèvement pendant la phase claire. Cette teneur modeste en CO2 fait du bien pour les poissons puisque il existe une dose létale à partir de laquelle les poissons meurent (d’après Sacchi et Testard en 1971)
**Calcium**

Les teneurs des eaux en calcium sont comprises entre 8.9 et 12.3 mg/l. Les eaux sont molles reflétant la pauvreté des sols ferralitiques de Madagascar. On peut toutefois remarquer que les teneurs augmentent régulièrement aux mois de février. Ce serait à cause du reliquat de chrysalide non consommé par les poissons qui restitue dans l'eau le calcium contenu dans les cellules; on peut voir les effets positifs de l'apport de chrysalide de provende: amélioration de la teneur en calcium.

**Magnésium / Calcium**

Dans toutes les rizières Mg : Ca < 1. On est dans les normes où les actions antagonistes du Mg sur l'absorption du calcium ne commencent pas encore à se manifester Sacchi et Testard en 1971.

**Phosphate**

Le phosphate est l'indice fondamental de la fertilité chimique d'un écosystème et par conséquent, de sa capacité productive. Les teneurs sont comprises entre 0.5 et 0.9 mg/l. C'est surtout au mois de décembre que la teneur est élevée, effet de l'apport de fumure organique. Les teneurs diminuent au mois de février puisque le phosphate est utilisé pour la fabrication de matière organique. Cependant, la dose n'est pas annulée totalement puisque la chrysalide est riche en phosphate et cet élément est restitué dans l'eau. On voit que dans les rizières à 0% de chrysalide, la teneur en phosphate diminue notablement. Dans les autres, la dose diminue mais le manque est pallié par le biais de l'apport de provende: fumure phosphatée (Tableau 4). Les teneurs s'échelonnent d'une teneur en chrysalide de la provende à l'autre.

**Silicate**

Il y a une certaine analogie entre cycle du phosphate et celui du silicate. Le silicate dépend uniquement des ressources de la lithosphère et de l'hydrosphère puisqu'il n'y en a pas dans l'air. Sacchi et Testard en 1971 propose que l'eau devrait contenir 30 - 40 mg de silice par m³. On est dans la bonne dose pour cet élément.

**L’Azote: (azote ammoniacal et azote nitreux)**

La fumure organique, apportée, les détritus autochtones dans les rizières sont dégradés par les bactéries de putréfaction et donne comme produits finaux l'eau, l'anhydride carbonique et l’ammoniaque, d’un côté, qui par l’intermédiaire de l’hydroxylamine donne les produits oxydés: nitrates et nitrites. De l’autre côté dans ces rizières, la chrysalide riche en protéines restitue dans l’eau les azotes contenus dans les cellules. Ce qui fait que les teneurs en azote s’échelonnent aussi suivant la concentration en chrysalide: dose élevée dans les rizières à taux élevés en chrysalides pour les rizières à 25% - 30%.

3.2 – 3.9 mg/l contre 0.5 – 0.9 mg/l dans les rizières témoins pour l’azote ammoniacal et 12 – 12.4 mg/l dans les rizières à 25 – 30% contre 0.6 – 2 mg/l dans les rizières témoins pour l’azote nitreux.

On remarque en février une chute régulière dans toutes les rizières. Il y a cependant apport continuellement tant en azote ammoniacal qu’en azote nitreux par le biais de l’apport de provende.

On peut dire, par ces constatations que la chrysalide moulue a deux actions positives dans l’eau: une action nutritive, c’est une nourriture pour les poissons et une action fertilisante, dans la mesure où il y a restitution de certains éléments fertilisants dans l’eau.

**La nourriture naturelle**

Le Tableau 2 montre le biovolume du plankton et le nombre des organismes du benthos récoltés respectivement dans les rizières. Il y a deux phases de production: jusqu’à la première moitié du mois de février, toutes les rizières sont bien garnies en nourritures naturelles; les poissons sont bien nourris et la production est assurée.
Les différences sont notables à partir de la deuxième moitié du mois de février; toutes les rizières à 15%, 25% et 30% de chrysalide contiennent suffisamment d’organismes tant planctoniques que benthiques pour nourrir à bien les poissons. Les biovolumes du plancton sont supérieurs à 1.5cc et les éléments benthiques supérieurs à 25 individus / dm$^3$. Dans les rizières à 0% et 7.5% de chrysalide, la production de nourritures naturelles est dérisoire. Le biovolume du plancton est inférieur à 1.5cc cela ne suffit pas pour nourrir à bien les poissons d’après Schlumberg O en 1982. Cela peut être mis en relation avec la qualité physico-chimique des eaux: par le biais des reliefs de provende non consommé par les poissons, les rizières sont fertilisés. Il y a apport soutenu d’éléments fertilisants et la capacité biogénique est élevée.

**Qualité de la nourriture naturelle**

Les rizières ont une richesse spécifique élevée tant pour les organismes autotrophes que pour les hétérotrophes.

**ESPECES DOMINANTES**

Après dépouillement, on peut voir que certaines espèces sont dominantes:

Les Rotifères: Ce sont des nourritures très recherchées par les alevins. Les espèces dominantes sont:
- Brachionus falcatus
- Brachionus calyciflorus
- Keratella cochlearis
- Notolca acuminata

Les Cladocères sont aussi en quantité importante: Daphnia pulex, Moina rectirostris, Diaphanosoma brachyata. Ces animaux sont aussi des nourritures naturelles très recherchées par les poissons.

L’avantage concernant la succession des espèces. C’est que les Cladocères abondent au moment où les Rotifères commencent à diminuer (en quantité).

Vers la deuxième quinzaine du mois de décembre les larves d’insecte aquatiques benthiques apparaissent; cela coïncide avec le régime alimentaire des poissons qui deviennent benthophages (Ralambomanana O en 1994): Parastenocaris dentilata, Bryocamptus cuspidatus sont les harpacticoïdes dominants. Concernant les microinvertébrés, on a Piscicola salmonsitica, Haemopis sanguisuga, Lumbricus variegatus, Chironomus plumosus, Chironomus tentas, Palmopia tibialis, Culex pipiens, Tipula ignobilis, Tabanus atratus.

Vers le mois de Janvier, c’est le cyclopide qui est prédominant: Halicyclops magniceps, Tropocyclops prasinus, Cyclops cuspidatus.

Pour les organismes autotrophes: Scenedesmus falcatus, Pediastrum integrum, Ankistrodesmus falcatus, Zygnema cylindricum, Cosmarium marginatum, Stauroastrum subcruciatum, Diatoma vulgar, Neidium productum, Navicula cuspidata, Surirella hisseriata, Gomphonema olivaceum.

On peut dire que la structure de ces réseaux trophiques des rizières est bien organisée, sur laquelle repose l’intensité de la production piscicole, objectif principal de l’exploitation. Les eaux sont riches, la capacité biogénique est élevée pour les eaux des rizières à 15%, 25% et 30% de chrysalide surtout.

Le problème dans cette production est que certaines espèces, par exemple, Diaphanosoma brachyata, sont peu abondantes dans les rizières mais sont très recherchées par les poissons. D’autres sont très abondantes mais sont rejetées par les poissons, par exemple Tropocyclops prasinus, les carpes n’en veulent pas (Ralambomanana O. 1994). Le choix de telle ou telle espèce, forme d’aliment dépend de plusieurs choses: faculté du poisson à engloutir, goût de l’animal proie et tant d’autres. C’est par la production piscicole obtenue qu’on mesure l’effet de la nourriture naturelle sur les poissons.

**QUANTITE DE NOURRITURE**

Si on se réfère au Tableau 2, on voit que la nourriture naturelle produite est suffisante dans toutes les rizières jusqu’à la première quinzaine du mois de Février. C’est surtout à partir de la deuxième quinzaine du mois de février que la nourriture est dérisoire dans les rizières témoins (partie hachurée). Dans les rizières à 7.5% de chrysalide, la crise commence vers le mois de mai. Dans les autres rizières à 15%, 25% et 30%, il y en a assez pour nourrir les poissons durant toute l’expérimentation. C’est toujours à cause de la qualité des eaux. Elles sont fertilisées par la provende apportée pour AMAS 2001. Food and Agricultural Research Council, Réduit, Mauritius.
nourriture des poissons et la production augmente. Dans les rizières à 7.5%, l’action fertilisante est limitée.

On peut conclure que la chaîne trophique présente correspond très bien aux exigences des poissons. La composition de la biocénose est adaptée aux exigences alimentaires des poissons.

**Production piscicole**

Les dimensions des rizières sont comprises entre 1.34 ares et 1.68 ares. Les poissons ont même condition de vie, même espace. Les rizières ont les mêmes traitements, signifiant qu’elles ont les mêmes potentiels de production de nourriture naturelle.

La vidange finale: Depuis le déversement jusqu’à la vidange finale, il n’y avait pas de pêche de contrôle pour ne pas détériorer les plants de riz. Les différences concernant la production piscicole se font voir lors de la vidange finale.

Le taux de survie: un cas est à écarter pour la comparaison:
Bloc I 1ère année: traitement 7.5% de chrysalide où il y avait un vol : le taux descend jusqu’à 45.4%.
Pour tout le reste le taux de survie est élevé: 80 - 100% puisque les poissons ont été nourris artificiellement même pour les rizières témoins et naturellement par le biais de l’apport de fumure organique.
Ce taux de survie élevé suppose aussi que ces poissons ont pu endurer les différentes difficultés: chocs thermiques, fluctuation des différentes doses de la qualité physico-chimique, stress écologiques, maladies etc.

**Le gain moyen quotidien**

Un deuxième cas à écarter est celui du bloc III 2ème année, traitement 30% ; le cheptel est atteint de maladie de la peau. La croissance est très faible; si bien qu’au terme de l’expérimentation le poids moyen est seulement de 168.3 g.
Le gain moyen quotidien est faible dans les rizières témoins 31gj-1. Le maximum de gain moyen quotidien est celui des rizières à 25% de chrysalide
3.68 – 3.79 gj-1 pour la première année
3.78 – 3.8 gj-1 pour la deuxième année.
Il y a aussi des valeurs intermédiaires pour les rizières à 7.5% et 15%. Tant en taille qu’en poids, il y a une supériorité pour les poissons nourris avec 25% par rapport à ceux nourris avec 30%.

**PRODUCTION A L’ARE**

La production est différente selon la teneur de la nourriture en chrysalide. La production la plus faible est 31.76 – 37.7 g are-1j-1 pour la première année. Elle est maximum pour la teneur 25% de chrysalide
143.58– 151.60 g are-1j-1 pour la 1ère année
147.10– 158.47 g are-1j-1 pour la 2ème année
Il y a aussi des valeurs intermédiaires pour les teneurs 7.5 - 15%. Les valeurs des tailles et poids sont voisines pour les teneurs 25 et 30%, avec une légère supériorité de la teneur 25%. Ces valeurs sont élevées par rapport à celles trouvées par (Kiener A. 1960): 1an 250 – 300gr.

**TAILLE ET POIDS**

Newmans et Keuls à la place de la plus petite différence significative.
On a les chiffres suivants pour la taille:

<table>
<thead>
<tr>
<th>SNK grouping</th>
<th>N</th>
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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>22.546</td>
<td>174</td>
</tr>
<tr>
<td>A</td>
<td>22.122</td>
<td>181</td>
</tr>
<tr>
<td>A</td>
<td>21.064</td>
<td>140</td>
</tr>
<tr>
<td>B</td>
<td>17.883</td>
<td>180</td>
</tr>
<tr>
<td>C</td>
<td>15.782</td>
<td>156</td>
</tr>
</tbody>
</table>

Les différences sont significatives surtout pour le poids Pr > F = 0.0001. Les poids obtenus sont tous supérieurs à ceux obtenus dans les rizières témoins. Cela prouve que la concentration en chrysalide détermine la croissance des poissons. C’est à cause de la teneur élevée en protéine de la chrysalide. Plus on augmente la teneur plus la croissance augmente avec une limite à 25%. Au-delà de cette concentration, la réponse à la croissance est négative.

Pour les tailles les différences ne sont pas significatives pour les poissons dans les rizières à 25, 30 et 15 % SNG grouping A. C’est surtout pour 7.5 et 0% que les différences sont significatives. Concernant les poids, les différences sont hautement significatives. SNG grouping A B C D E. Cela prouve que la teneur en chrysalide a une influence très marquée sur la croissance des poissons puisque le taux de protéines est élevé.

**CONCLUSION GENERALE**

Les chiffres obtenus nous laissent conclure que l’apport de provende de chrysalide a changé la qualité physico-chimique des eaux par le biais des restes de provende. Les eaux sont propices à la carpiculture. Cela fait aussi que la production de nourritures naturelles est améliorée puisque le milieu est favorable. Le milieu fertilisé par la chrysalide permet la prolifération du plancton et des différentes larves d’insectes aquatiques. La nourriture naturelle, étant abondante, entraîne une augmentation de la production piscicole. A plus forte raison, l’apport de provende de chrysalide accentue énormément l’intensification. Durant 94 jours d’élevage le poids atteint environ 350g. Le résultat est prometteur. La teneur 25% de chrysalide incorporée dans la provende paraît la meilleure teneur, permettant d’avoir le meilleur résultat.

La chrysalide, étant un sous-produit d’élevage de ver à soie ne coûte pas cher. Mais elle est employée pour augmenter la production piscicole, en diminuant le prix de revient de la provende pour poisson.

L’utilisation de chrysalide permet d’augmenter la production piscicole par la fabrication de provende à bas prix de revient.
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SEASONAL DISTRIBUTION OF POTENTIALLY TOXIC BENTHIC DINOFLAGELLATES IN THE LAGOON OF TROU AUX BICHES, MAURITIUS

MD Hurbungs, N Jayabalan and V Chineah
Albion Fisheries Research Centre

ABSTRACT

The distribution pattern of the benthic dinoflagellates such as Gambierdiscus toxicus, Ostreopsis spp., Prorocentrum spp., Coolia monotis and Amphidinium sp. associated with macroalge was studied for a period of two years from January 1998 to December 1999 in the lagoon at Trou aux Biches along the western coast of Mauritius. While Amphidinium sp. was dominant (32.5%) during 1998 Prorocentrum spp. were abundant (54.7%) during 1999 in the lagoon. The density of G. toxicus ranged from 0 to 4 cells g⁻¹ wet weight of macroalga and the density of other dinoflagellates varied considerably. Among the physico-chemical characteristics of the water such as temperature, salinity, dissolved oxygen, pH and the nutrients like NO₃-N and PO₄, the values of temperature and dissolved oxygen had comparatively wider fluctuations than the other parameters. Statistical analysis of the results indicated that the variations in the dinoflagellate populations between the months were not significant (P>0.05) both during 1998 and 1999.

Key words: lagoon, benthic dinoflagellate, water quality, ciguatera

INTRODUCTION

In ciguatera endemic regions, the benthic dinoflagellate Gambierdiscus toxicus along with other dinoflagellates belonging to the genera Ostreopsis, Prorocentrum and Amphidinium are presumed to be the elaborators of ciguatoxins in fishes (Yasumoto et al., 1977; Adachi and Fukuyo, 1979; Tindall et al., 1984; Holmes et al, 1990; Lewis and Holmes, 1993; Holmes and Lewis, 1994; Taylor et al., 1995). Incidences of fish toxicity in Mauritius are known since 1601 (Halstead and Cox, 1973). Though, the presence of G. toxicus has been reported from Mauritian waters (Bagnis, 1980), no detailed information is available on the seasonal and temporal distribution of any of the bloom forming toxic dinoflagellates of Mauritius. The present study deals with the distribution pattern of some potentially toxic benthic dinoflagellates in relation to the physico-chemical characteristics of the water from the lagoon at Trou aux Biches.

MATERIALS AND METHODS

Samples of macroalgae (Jania sp., Gracillaria sp. and Hypnea sp.) were collected once a month from 2 locations between January 1998 and December 1999 from the lagoon at Trou aux Biches in the western coast of Mauritius (Figure 1). The macroalgae were hand picked and placed in polythene ziplock bags containing the sea water and transported to the laboratory. The technique followed for isolation of epiphytic dinoflagellates from the macroalgae and the species-wise quantitative estimation was described elsewhere (Chineah et al., 1999). The number of dinoflagellates present has been expressed for the pooled samples of macroalgae as number of cells per gram wet weight (No. of cells g⁻¹) of the macroalga.

For the physico-chemical parameters of the water such as temperature, salinity, dissolved oxygen, pH and nutrients like nitrate-nitrogen (NO₃-N) and phosphate (PO₄), water samples were collected from the sites as that of macrophytes in the lagoon using clean glass bottles. The procedure followed for the
estimation of the physico-chemical parameters of the water was similar to the one as described earlier (Chineah et al., 1999). Results were analysed with ANOVA using Excel Data Analysis System.

**RESULTS AND DISCUSSION**

Altogether, 11 species of benthic dinoflagellates belonging to the genera, *Gambierdiscus*, *Prorocentrum*, *Ostreopsis*, *Coolia* and *Amphidinium* were observed in the lagoon. All the genera have toxic species (Taylor et al., 1995; Steidinger and Tangen, 1996). During the present investigation, the following species such as *G. toxicus*, *P. lima*, *P. concavum*, *P. emarginatum*, *P. mexicanum*, *Prorocentrum sp.*, *O. lenticularis*, *O. ovata*, *Ostreopsis sp.*, *C. monotis* and *Amphidinium sp.* were recorded.

The seasonal distribution of dinoflagellates in the Trou aux Biches lagoon during 1998 and 1999 is given in Tables 1 and 2 respectively. While *Amphidinium* sp. dominated (32.5%) over other species during 1998 followed by *Prorocentrum* sp. (27.3%) and *Coolia monotis* (21.4%); during 1999, *Prorocentrum* spp. were dominant (54.7%). The total number of cell counts was highest (27 cells g⁻¹ of macroalga) during March in 1998 and during November (58 cells g⁻¹ of macroalga) in 1999. Though the distribution pattern of dinoflagellates showed an irregular trend both the years, *Ostreopsis* sp. and *Prorocentrum* sp. occurred in higher numbers during 1999 than during 1998.

The water quality parameters in the lagoon at Trou aux Biches during 1998 and 1999 are shown in Tables 3 and 4. The values of salinity in Trou aux Biches had narrow range (34.0‰ - 35.8‰). Temperature and dissolved oxygen values ranged between 23.6°C and 30.0°C, and between 5.8mg l⁻¹ and 10.0mg l⁻¹ respectively. While pH ranged from 8.1 to 8.5, low values of NO₃-N and PO₄ were observed.

The species composition of dinoflagellates in the present study is in general agreement with the observation made in the Albion lagoon (Chineah et al. 1998) and in Reunion Island (Quod et al. 1995).
Hence, it appears that there may not be much difference in the distribution pattern and species diversity of benthic dinoflagellates between Mauritius and Reunion Island.

### Table 1 Distribution of benthic dinoflagellates in the Trou aux Biches lagoon during 1998

<table>
<thead>
<tr>
<th>Month</th>
<th>G. toxicus</th>
<th>Ostreopsis spp</th>
<th>Prorocentrum spp.</th>
<th>Coolia monotis</th>
<th>Amphidinium sp</th>
<th>Total No. of cells</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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<td>2</td>
<td>4</td>
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<tr>
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<td>5</td>
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<td>0</td>
<td>4</td>
<td>13</td>
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<td>17</td>
</tr>
<tr>
<td>Aug</td>
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<td>3</td>
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<td>4</td>
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<td>15</td>
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<tr>
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<td>8</td>
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<tr>
<td>%</td>
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<td>8</td>
<td>27</td>
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</table>

### Table 2 Distribution of benthic dinoflagellates in the Trou aux Biches lagoon during 1999

<table>
<thead>
<tr>
<th>Month</th>
<th>G. toxicus</th>
<th>Ostreopsis spp</th>
<th>Prorocentrum spp.</th>
<th>Coolia monotis</th>
<th>Amphidinium sp</th>
<th>Total No. of cells</th>
</tr>
</thead>
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<td>0</td>
<td>0</td>
<td>3</td>
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<td>8</td>
<td>17</td>
</tr>
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<td>0</td>
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</tr>
<tr>
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<td>8</td>
<td>11</td>
</tr>
<tr>
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<td>30</td>
</tr>
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</tr>
<tr>
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<td>123</td>
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<td>27</td>
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</tr>
<tr>
<td>%</td>
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<td>19</td>
<td>55</td>
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</tbody>
</table>
Table 3  Physico-chemical parameters of water in Trou aux Biches lagoon during 1998.

<table>
<thead>
<tr>
<th>Month</th>
<th>Salinity %</th>
<th>Temperature ºC</th>
<th>Dissolved O₂ mg/l</th>
<th>pH</th>
</tr>
</thead>
<tbody>
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<td>Jan</td>
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<td>30.0</td>
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<td>8.1</td>
</tr>
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<td>35.0</td>
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<td>7.0</td>
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</tr>
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<td>35.0</td>
<td>29.0</td>
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<td>8.1</td>
</tr>
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<td>9.8</td>
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</tr>
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<td>24.7</td>
<td>10.0</td>
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</tr>
<tr>
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<td>26.9</td>
<td>6.7</td>
<td>8.1</td>
</tr>
<tr>
<td>Dec</td>
<td>35.0</td>
<td>28.0</td>
<td>5.8</td>
<td>8.2</td>
</tr>
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</table>

Table 4  Physico-chemical parameters of water in the Trou aux Biches lagoon during 1999.

<table>
<thead>
<tr>
<th>Month</th>
<th>Salinity %</th>
<th>Temperature ºC</th>
<th>pH</th>
<th>Dissolved O₂ mg/l</th>
<th>NO₃-N</th>
<th>PO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>35.6</td>
<td>27.6</td>
<td>8</td>
<td>6.4</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>34.8</td>
<td>27.0</td>
<td>8</td>
<td>6.5</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Mar</td>
<td>35.4</td>
<td>27.2</td>
<td>8</td>
<td>6.5</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Apr</td>
<td>35.1</td>
<td>28.0</td>
<td>8</td>
<td>6.9</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>35.6</td>
<td>27.5</td>
<td>8</td>
<td>7.0</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Jun</td>
<td>34.9</td>
<td>25.8</td>
<td>8</td>
<td>7.1</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Jul</td>
<td>35.8</td>
<td>24.2</td>
<td>8</td>
<td>7.3</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
<tr>
<td>Aug</td>
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<td>24.9</td>
<td>8</td>
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<td>0</td>
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<tr>
<td>Sept</td>
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<td>24.0</td>
<td>8</td>
<td>7.1</td>
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<tr>
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<tr>
<td>Nov</td>
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<td>6.3</td>
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<td>0</td>
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<tr>
<td>Dec</td>
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<td>8</td>
<td>6.1</td>
<td>&lt; 0.1</td>
<td>0</td>
</tr>
</tbody>
</table>

The density of *G. toxicus* recorded in the present study is very low (0-4 cells g⁻¹ of macroalgae). Similarly a low value (0-15 cells g⁻¹ of macroalgae) of *G. toxicus* was observed in the Albion lagoon (Chineah et al., 1998) unlike in French Polynesia where its density varied from 0-54 000 cells g⁻¹ of macroalgae (Yasumoto et al., 1984). Hence, it appears that the lagoons in Mauritius may harbour less population density of *G. toxicus*.

*G. toxicus* produces gambiertoxins, the progenitors of ciguatoxins, GTX-3C (Satake et al., 1993), GTX-4B (Murata et al., 1990; Legrand et al., 1992) and the CTXs and maitotoxins-MTXs that accumulate in fish tissues (Murata et al., 1990; Lewis et al., 1990; Holmes and Lewis, 1994). It is speculated that the toxicity level in *G. toxicus* differs between the strains of different geographical regions. The disparity in toxin production among the acclimated strains in the laboratory suggested the genetic variability among the strains of different geographical regions (Bomber et al. 1989). Further, in various isolates of *G. toxicus*, the ability of producing Na⁺ and Ca⁺⁺ ion channel active components varied considerably (Sperr and Doucette, 1996). Toxicity studies with cultured *G. toxicus* from Mauritius would explain the variability of toxicity, if any, between the strains.

Excepting the species *G. toxicus* that has been recognised as the causative agent of ciguatera elsewhere (Yasumoto et al., 1977; Adachi and Fukuyo, 1979) and, *P. lima* and *O. lenticularis* believed to be the progenitors of ciguatera (Quod et al., 1995; Taylor et al., 1995), the role of other species causing ciguatera has yet to be established. However, the dinoflagellates such as, *P. lima*, *P. concavum* and *Amphidinium carterae* are known to produce certain biologically active compounds. While, the species *P. concavum* contributes to okadaic acid (OA) production in the Caribbean (Dickey et al., 1990);
\textit{P. lima} is implicated as the producer of OA (Bomber and Aikman, 1988) as well as dinophysistoxin-1 (DTX-1) in French West Indies (Bourdeau et al., 1995). Both the species are represented in the Mauritian waters. Further, the species \textit{P. lima} produces resting cysts during unfavourable conditions (Faust, 1990) and the cyst germination may provide an inoculum for subsequent blooms. Since, \textit{Prorocentrum} spp. were dominant in the lagoon during 1999, monitoring of the cyst dynamics in the lagoons is needed.

Among the species of \textit{Ostreopsis}, \textit{O. lenticularis} is suggested to be a contributor of ciguatera syndrome and \textit{O. ovata} to produce mild water-soluble toxic compounds (Taylor et al., 1995). Both the species are distributed in appreciable numbers in the lagoon of Mauritius, besides a third \textit{Ostreopsis} sp. The annual percentage contribution of \textit{Ostreopsis} sp. to the total benthic dinoflagellate population in Trou aux Biches ranged from 7 to 19 (Tables 1 and 2) indicating as an important component of dinoflagellate assemblage of Mauritius.

The dinoflagellate, \textit{C. monotis} was either reported to be non-toxic (Yasumoto et al., 1980; Tindall et al., 1984; Carlson and Tindall, 1985) or mildly toxic (Fukuyo and Ishimaru, 1986; Steidinger and Tangen, 1996) and haemolytic (Nagajima et al., 1981). In the present study, \textit{C. monotis} was recorded in appreciable quantity in Trou aux Biches (Tables 1 and 2). However, in the waters of Reunion Island, while no \textit{Coolia} sp. could be collected (Quod et al., 1995), very low levels of population have been reported from French West Indies (Bourdeau et al., 1995).

The genus \textit{Amphidinium} is represented by about 100 species (Steidinger and Tangen, 1996). The identity of the species of \textit{Amphidinium} collected during the present investigation could not be established. However, \textit{A. carterae} produces haemolytic compounds and may be implicated in ciguatera (Taylor et al., 1995) and \textit{A. operculatum} distributed in temperate and tropical coastal waters is toxic (Steidinger and Tangen, 1996).

ANOVA showed that the variation in the dinoflagellate population in the lagoon at Trou aux Biches between months was not significantly different (P>0.05) both during 1998 and 1999. On the other hand, while the variation in the number of dinoflagellates representing various genera was not significant during 1999 (\(P>0.05\)), the variations was significant during 1999 (\(P<0.05\)).

The Island of Mauritius is an endemic region of fish toxicity especially ciguatera and hence, several potentially ciguateric fish species have been banned from marketing (GOM, 1986; 1996). The distribution of several species of potentially toxic benthic dinoflagellates in the waters of Mauritius as normal flora is a matter of concern. Besides, the natural disturbances and the anthropogenic eutrophication and industrial development that disturb the environment and trigger toxic algal blooms are added concerns. Also, the introduction of new toxic species, especially the cysts from ballast water of commercial ships from other regions is a possibility. Routine algal monitoring as a basic method for public warning against toxic algae and dissemination of information on their role in fish toxicity would help increase public awareness and voluntary rejection of toxic fish species.

**CONCLUSION**

Occurrence of several species of potentially toxic benthic dinoflagellates in the waters of Mauritius has to be viewed as a threat to seafood safety. Monitoring of toxic microalgae especially bloom forming ones in the waters of Mauritius would help to better understand the problem of ciguatera.

**ACKNOWLEDGEMENTS**

The authors are thankful to the Principal Fisheries Officer, Albion Fisheries Research Centre for his keen interest and encouragement and the Ministry of Fisheries, Government of Mauritius for facilities provided.
REFERENCES


AN INVESTIGATION ON THE PHYSICO-CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF THE LAGOON OF FLIC-EN-FLAC, MAURITIUS

V Chineah, V Chooramun, M Nallee, Y Basant Rai, R Moothien Pillay, N Jayabalan, H Terashima and A Terai

ABSTRACT

An investigation on the physico-chemical and biological characteristics of the lagoonal water at Flic-en-Flac was carried out between January 1999 and October 2000 to understand the ecological status of the lagoon. The temperature of the water fluctuated from 23.0°C to 29.0°C and the salinity varied from 34.3 to 35.3 ‰. Dissolved O₂ ranged between 6.5 and 9.4 mg L⁻¹. The values of pH and nitrate showed narrow fluctuations. While the level of phosphate recorded varied from <0.01 mg L⁻¹ to 0.06 mg L⁻¹, chemical oxygen demand was low (0.1 mg L⁻¹ - 1.3 mg L⁻¹). The current pattern in the lagoon is complex and weak with a velocity of 0.02 - 0.25 ms⁻¹ during ebb tide and 0.01 - 0.31 ms⁻¹ during the flood tide. While, the flow of current close to the shore indicates both northerly and southerly movements, nearer to the reef, the movement is towards the pass. Live coral cover was higher in the forereef zone than the lagoonal areas. In the lagoon, coral community was dominated mainly by the branching corals such as Acropora muricata and A. intermedia; other species of lesser importance were A. tenuis, Pavona decussata, Pocillopora damicornis, Platygrya daedalea, Porites rus, P. nigrescens and P. lutea. Of the 28 species of fishes encountered during the observation, majority of them were juveniles. Besides 5 species of seagrass, benthic invertebrates like sea cucumber and sea urchin found in the lagoon bed showed zonal preference. Although, there was significant difference (p<0.05) between monthly distribution pattern of total coliform (TC) and faecal coliform (FC) bacteria, the number was within the guideline limits prescribed for coastal water quality.

Key words: lagoon, water quality, current, coral, seagrass, fish, coliform bacteria;

INTRODUCTION

The ecological security of the coastal zone and the coastal seas is at stake due to intense industrial activities, increased multinational investments and rural areas getting urbanised. A proper approach to effectively manage the coasts and marine environment requires detailed information of water quality, sediment quality and biological characteristics of the intertidal and nearshore waters. In this context, the biodiversity rich areas like the coral reefs and lagoons deserve attention. Information available on the ecological status of the lagoons of Mauritius is scanty (MFMR, 1998; Chineah et al. 1999). The present paper deals with the distribution pattern of physico-chemical characteristics and the coliform bacterial indicators in the lagoonal waters of Flic-en-Flac between January 1999 and October 2000. Also, the pattern of current in the lagoon studied during April 1997-December 1998 and the results of a survey conducted during July 2000 on the substrate cover, macroflora, benthic invertebrates and ichthyofauna are reported.

Study area

The lagoon in Flic-en-Flac (Figure 1) is situated in the mid-western coast of Mauritius (Lat.20°18’S and Long. 57°21’E). The fringing coral reef that runs almost parallel to the coast at a distance of 600m from the shoreline possesses 7 passes and encloses a water-spread area of 2.5 Km². The lagoon proper is shallow ranging in depth from 0.5m to 2.0m. The shoreline of the lagoon originates opposite Passe Flic en Flac in the north and ends at Passe Badamier in the south with a flat fine sandy beach running to a length of about 4.5Km. It is a popular public beach, on which stand several luxury hotels and resorts. The semidiurnal tidal influence is less significant with an amplitude of 0.65m. While, erosion of the
beach along the shoreline in the southern part is apparent and that measures have been taken to construct gabion walls against further erosion, there is clear indication of sand accretion in the north.

**Figure 1** Location of sampling stations and general current pattern in the Flic en Flac lagoon

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**MATERIALS AND METHODS**

**Physico-chemical parameters of water**

Water samples for the estimation of physico-chemical parameters such as temperature, salinity, dissolved O₂, pH, chemical oxygen demand (COD) and nutrients like nitrate-nitrogen (NO₃-N) and phosphate (PO₄) were collected once every 3 months between January 1999 and October 2000 from 5 stations. The location of the stations (station-1: near fish landing station; station-2: near Villas Caroline Hotel; station-3: near lime-kiln; station-4: near la Pirogue Hotel and station-5: in the lagoon opposite the lime kiln) is shown in **Figure 1**. Analyses of the water samples for physico-chemical parameters were made adopting the standard procedures described earlier (Chineah et al. 1999).

**Current pattern**

The direction and speed of the current in the lagoon was studied from April 1997 to December 1998 by drogues adopting the Langrangian method. The position of the drogues deployed was located using a
Scout Master GPS set up to read positions in the Universal Transverse Mercator (UTM) projection system (Chineah et al. 1999). The velocity of the current in the lagoon based on the drogue movement is expressed as metre per second (ms⁻¹). Data on speed and direction of wind for the corresponding period of study were obtained from the Meteorological Station located at the Medine Sugar estate.

**Survey of substrate cover, macrophytes and fauna**

Studies on substrate cover, and the qualitative and quantitative estimations of corals, echinoderms and fish in the lagoon were made by diving during July 2000 at 4 zones namely, nearshore zone (zone-1), midlagoon zone (zone-2), back reef zone (zone-3) and fore reef zone (zone-4) (Figure 1). While 200 m transect line parallel to the coast was laid for observation in zones-1, 2 and 3; in zone-4, three 20m transect lines were set for observation. An area of 158,250m² was surveyed using the point intercept technique as suggested by Kaly et al., (1997) with slight modification. As most of the fishes collected were juveniles, as far as possible the identification was done either up to generic or species level. The substrate cover in the lagoon was classified as live coral (LC), dead coral (DC), macroalgae (MA), seagrass (SG), turf algae (TA), rubble (R) and sand (S).

**Coliform bacteria**

Monthly collection of lagoon water was made aseptically using sterile water bottles from 4 stations (station 1: opposite Ocean Restaurant; station-2: opposite lime-kiln; station-3: beside Pearl Beach Hotel; station 4: opposite Sugar Beach Hotel) (Figure 1) during January 1999 - October 2000. The standard procedures adopted for inoculation, incubation, isolation, identification and enumeration of total coliform (TC) and fecal coliform (FC) bacteria were detailed elsewhere (Basant Rai et al. 1998; Chineah et al. 1999). The number of bacteria present has been expressed as colony forming units (CFU) per 100ml of water. For statistical interpretation (ANOVA) of results, the values were transformed into log and further analysis was performed with Excel data analysis system.

**RESULTS**

**Physico-chemical parameters**

**Temperature**

Distribution of surface water temperature during the period of study is provided in Figure 2. The values ranged from 23.0 to 28.5 °C in station-1, from 23.5 to 29.0 °C in station-2, from 23.5 to 28.0 °C in stations 3, 4 and 5. While higher values were recorded during January of 1999 and 2000 in all the stations, lower values were recorded during October 2000.

**Salinity**

The salinity variations of the water at different stations (Figure 2) ranged from 34.3 to 35.3‰. The fluctuations in salinity values indicate that there is some fresh water input from land. The lowest value was recorded in station-1 during January 2000 and the highest value was in station-4 during October 1999.

**pH**

The range of pH values in various stations is given in Figure 2. The highest pH value (8.3) was recorded in station-3 during July 1999 and the lowest value (7.8) during January 2000 in both stations-1 & 2. The data indicate the alkaline nature of the lagoon water.

**Dissolved oxygen**

The DO values (Figure 2) varied between 6.8 mg l⁻¹ and 7.7 mg l⁻¹ at station 1, between 6.5 mg l⁻¹ and 7.5 mg l⁻¹ at station 2, between 6.8 mg l⁻¹ and 8.3 mg l⁻¹ at station 3, between 6.9 mg l⁻¹ and 9.3 mg l⁻¹ at
station 4 and between 7.3 mg l⁻¹ and 9.4 mg l⁻¹ at station 5. The lowest value was recorded during October 2000 and the highest value was observed during October 1999.

**Chemical oxygen demand**

The highest value (1.3 mg l⁻¹) of COD was recorded in station 2 during January 2000 and lowest value (0.1 mg l⁻¹) in station-5 during October 2000 (Figure 2). Station 5 almost always recorded lesser values of COD.

**Nitrate-nitrogen (NO₃-N)**

The concentrations of NO₃-N obtained at all the stations were low. The values varied from < 0.1 mg l⁻¹ to 0.2 mg l⁻¹ at stations 1 and 2; while, in stations 3, 4 and 5, the values ranged from < 0.1 mg l⁻¹ to 0.1 mg l⁻¹ (Figure 2).

**Phosphate (PO₄)**

The fluctuations in phosphate levels of the water in the lagoon are shown in Figure 2. Trace values (< 0.01 mg l⁻¹) of phosphate concentrations were recorded during January 1999 in station 1 and January 1999 and October 2000 in station 5. The maximum value (0.06 mg l⁻¹) was noted in stations 1 and 2.

**Figure 2 Physicochemical parameters**

![Figure 2 Physicochemical parameters](image-url)
Current pattern

Table 1 provides the speed and direction of the current as well as wind velocity and direction during various months and at different tidal regimes. Within 1 m depth of the lagoon, speed of the current ranged from 0.01 ms\(^{-1}\) to 0.27 ms\(^{-1}\) during flood tide and from 0.02 ms\(^{-1}\) to 0.25 ms\(^{-1}\) during ebb tide. Figure 1 shows the drogue movement in the lagoon during the period of study. During most of the year, the wind velocity ranged from 8 Km\(^{\text{h}}\) to 20 Km\(^{\text{h}}\).

Table 1 Data collected during drogue deployments in the lagoon at Flic en Flac, during April 1997 - December 1998

<table>
<thead>
<tr>
<th>Date</th>
<th>No of drogues</th>
<th>Ebb Tide</th>
<th>Flood Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Speed</td>
<td>Wind</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m s(^{-1})</td>
<td>° N</td>
</tr>
<tr>
<td>3-Apr-97</td>
<td>5</td>
<td>0.02</td>
<td>134 NA</td>
</tr>
<tr>
<td>13-Jun-97</td>
<td>6</td>
<td>0.09</td>
<td>253 5 120</td>
</tr>
<tr>
<td>20-Jun-97</td>
<td>10</td>
<td>0.06</td>
<td>252 15 90</td>
</tr>
<tr>
<td>24-Oct-97</td>
<td>5</td>
<td>0.03</td>
<td>252 15 90</td>
</tr>
<tr>
<td>7-Nov-97</td>
<td>4</td>
<td>0.05</td>
<td>113 15 270</td>
</tr>
<tr>
<td>21-Nov-97</td>
<td>5</td>
<td>0.04</td>
<td>113 15 270</td>
</tr>
<tr>
<td>27-Nov-97</td>
<td>5</td>
<td>0.05</td>
<td>123 16 250</td>
</tr>
<tr>
<td>28-Nov-97</td>
<td>5</td>
<td>0.05</td>
<td>123 16 250</td>
</tr>
<tr>
<td>5-Dec-97</td>
<td>5</td>
<td>0.13</td>
<td>266 16 90</td>
</tr>
<tr>
<td>20-Mar-98</td>
<td>5</td>
<td>0.07</td>
<td>179 NA NA</td>
</tr>
<tr>
<td>27-Mar-98</td>
<td>5</td>
<td>0.03</td>
<td>179 NA NA</td>
</tr>
<tr>
<td>26-Sep-98</td>
<td>6</td>
<td>0.13</td>
<td>169 16 100</td>
</tr>
<tr>
<td>6-Nov-98</td>
<td>6</td>
<td>0.13</td>
<td>169 16 100</td>
</tr>
<tr>
<td>13-Nov-98</td>
<td>2</td>
<td>0.05</td>
<td>178 16 100</td>
</tr>
<tr>
<td>27-Nov-98</td>
<td>2</td>
<td>0.05</td>
<td>178 16 100</td>
</tr>
<tr>
<td>26-Dec-98</td>
<td>5</td>
<td>0.09</td>
<td>176 16 90</td>
</tr>
</tbody>
</table>

Substrate cover

Data on the substrate cover in nearshore, midlagoon, backreef and forereef zones (Figure 3) indicate that next to forereef zone, the midlagoon zone supports higher percentages of live coral. Macroalgae were present in higher percentages in all the zones except the forereef zone.

Seagrass and echinoderm

Seagrass in the lagoon was represented by 5 species namely, *Halophila stipulacea*, *H. ovalis*, *Syringodium isoetifolium*, *Thalassodendron ciliatum* and *Halodule uninervis*. The species composition and number of sea cucumbers and sea urchins recorded in nearshore, midlagoon and backreef zones are shown in Figure 4.
Status of the marine environment of the Flic en Flac lagoon, Mauritius. V. Chineah et al.

Figure 3 Substrate cover at Flic-en-Flac.

![Substrate cover at Flic-en-Flac](image)

Figure 4 Distribution of common invertebrates in the lagoon of Flic en Flac

![Distribution of common invertebrates in the lagoon of Flic en Flac](image)

While the sea cucumber, *Bohadschia* sp. recorded the highest number (309 per 1000 m$^2$) in nearshore zone, followed by *Stichopus chloronotus* in midlagoon zone, the highest number of sea urchins was recorded in backreef zone (970 per 1000 m$^2$).

Table 2 Distribution of echinoderms in the lagoon of Flic en Flac  Number / 1000 m$^2$

<table>
<thead>
<tr>
<th>Zone</th>
<th>Stichopus chloronotus</th>
<th>Bohadschia sp.</th>
<th>Holothuria atra</th>
<th>Synapta sp.</th>
<th>Other Holothuria species</th>
<th>Sea urchin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearshore</td>
<td>19</td>
<td>309</td>
<td>24</td>
<td>34</td>
<td>46</td>
<td>81</td>
</tr>
<tr>
<td>Midlagoon</td>
<td>151</td>
<td>55</td>
<td>22</td>
<td>37</td>
<td>-</td>
<td>134</td>
</tr>
<tr>
<td>Backreef</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>970</td>
</tr>
</tbody>
</table>
Coral population

Species of corals established in the lagoon are not very diverse and belong to 9 species viz. *Acropora muricata*, *A. intermedia*, *A. tenuis*, *Pavona decussata*, *Pocillopora damicornis*, *Platygrya daedalea*, *Porites rus*, *P. nigrescens* and *P. lutea*. While patchy distribution was evident in all the zones, dense population of the branching corals, such as *A. muricata* and *A. intermedia* were found in the midlagoon zone.

Fish fauna

Fishes in the lagoon belonged to 28 species representing 25 genera and 19 families (Figure 5, Table 3) indicating that the lagoon supports less species diversity. A majority of the individuals were smaller in size (< 15 cm) and the dominant ones were scarids, acanthurids, mullids, labrids and pomacentrids.

**Figure 5** Distribution of fish(family wise) in the lagoon of Flic en Flac

Coliform bacterial indicators

The estimated TC and FC values in the lagoon water samples are provided in Figures 6 and 7 respectively. While the TC varied from < 1 to 236 CFU / 100 ml of water in station 1, the FC values ranged from < 1 to 77 CFU / 100 ml. In station 2, the corresponding values were < 1 to 220 CFU / 100 ml and < 1 to 40 CFU / 100 ml of water. Both in stations 3 & 4, a wider range in the bacterial population was observed (i.e. TC < 1 to 300 CFU / 100 ml and FC < 1 to 90 CFU / 100 ml in station-3 and TC < 1 to 500 CFU / 100 ml and FC < 1 to 100CFU / 100 ml in station-4).
### Table 3 Distribution of fish in the Flic en Flac lagoon Number per 1000 m²

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Nearshore</th>
<th>Midlagoon</th>
<th>Backreef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muraenidae</td>
<td>-</td>
<td>sp.</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Holocentridae</td>
<td>Holocentrus</td>
<td>sp.</td>
<td>28</td>
<td>76</td>
<td>5</td>
</tr>
<tr>
<td>Fistulariidae</td>
<td>Fistularia</td>
<td>commersonii</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Scorpaenidae</td>
<td>Pterois</td>
<td>antennata</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Serranidae</td>
<td>Epinephelus</td>
<td>sp.</td>
<td>3</td>
<td>22</td>
<td>-</td>
</tr>
<tr>
<td>Apogonidae</td>
<td>Apogon</td>
<td>sp.</td>
<td>4</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Carangidae</td>
<td>Caranx</td>
<td>sp.</td>
<td>-</td>
<td>26</td>
<td>-</td>
</tr>
<tr>
<td>Lethrinidae</td>
<td>Gnathodentex</td>
<td>aurolineatus</td>
<td>300</td>
<td>86</td>
<td>-</td>
</tr>
<tr>
<td>Mullidae</td>
<td>Parupeneus</td>
<td>sp.</td>
<td>19</td>
<td>391</td>
<td>70</td>
</tr>
<tr>
<td>Chaetodontidae</td>
<td>Chaetodon</td>
<td>sp.</td>
<td>15</td>
<td>76</td>
<td>21</td>
</tr>
<tr>
<td>Pomacentridae</td>
<td>Abudefduf</td>
<td>sp.</td>
<td>2</td>
<td>12</td>
<td>261</td>
</tr>
<tr>
<td></td>
<td>Chromis</td>
<td>viridis</td>
<td>14</td>
<td>317</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Dascyllus</td>
<td>aruanus</td>
<td>225</td>
<td>541</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Stegastes</td>
<td>limbatus</td>
<td>11</td>
<td>203</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Stegastes</td>
<td>lividus</td>
<td>22</td>
<td>432</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Stegastes</td>
<td>nigricans</td>
<td>7</td>
<td>588</td>
<td>-</td>
</tr>
<tr>
<td>Labridae</td>
<td>Chellinus</td>
<td>sp.</td>
<td>2</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>sp.</td>
<td>46</td>
<td>313</td>
<td>131</td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>Leptoscarus</td>
<td>vaigiensis</td>
<td>316</td>
<td>217</td>
<td>168</td>
</tr>
<tr>
<td>Gobiidae</td>
<td>-</td>
<td>sp.</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zanclidae</td>
<td>Zanclus</td>
<td>cornutus</td>
<td>2</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Acanthuridae</td>
<td>Acanthurus</td>
<td>tristegus</td>
<td>8</td>
<td>99</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Acanthurus</td>
<td>sp.</td>
<td>37</td>
<td>188</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Naso</td>
<td>sp.</td>
<td>-</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Bothidae</td>
<td>Bothus</td>
<td>sp.</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Balistidae</td>
<td>Rhinocanthus</td>
<td>hauleatus</td>
<td>33</td>
<td>31</td>
<td>-</td>
</tr>
<tr>
<td>Ostraciidae</td>
<td>Ostracion</td>
<td>sp.</td>
<td>7</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

### Figure 6 Total colony counts Jan 1999 to Oct 2000

[Graph showing total colony counts from Jan 1999 to Oct 2000 with different colored lines for each category and a guideline limit.]
DISCUSSION

The results of the present study on the physico-chemical and biological characteristics of the lagoon at Flic en Flac revealed many features of interest.

Temperature in the lagoonal water shows a single peak during summer season (January 1999 and 2000) (Figure 2). The rate of evaporation of water due to the solar heating during summer would naturally increase the salinity of the water. However in the present study, lowest value of salinity has been observed in stations 1 and 2 during a summer month (January 2000) (Figure 2). This may be due to some input of fresh water to this part of the lagoon during the observation. The narrow range (7.8 - 8.3) of pH shows consistency in the distribution and the values are indicative of less organic load in the lagoon.

Dissolved oxygen values will have negative relationship with temperature and salinity. However, such relationship could not be established in the present study. The values of dissolved oxygen varied from 3.28 to 8.5 mg l\(^{-1}\) in the tropical estuaries (Thangaraj et al. 1979, Sivasankar and Jayabalain, 1994). The threshold dissolved oxygen level prescribed for quality of water in various countries varies between 5.0 mg l\(^{-1}\) and 6.5 mg l\(^{-1}\) (Basant Rai et al. 1998) and the prescribed guideline limit for the coastal water quality in Mauritius is 5.0 mg l\(^{-1}\). In the present study, the concentrations of dissolved oxygen were always > 6.5 mg l\(^{-1}\) in all the stations which are indicative of the quality of the lagoonal water.

The values of COD recorded in the present study are comparable with the values in the Albion lagoon except in a station nearer to the Belle eau river mouth (Chineah et al., 1999). The concentrations of NO\(_3\)-N and PO\(_4\) in the water at Flic en Flac ranged from < 0.1 to 0.2 mg l\(^{-1}\) and < 0.01 to 0.06 mg l\(^{-1}\) respectively. While the values of NO\(_3\)-N agrees with the earlier observation in the same lagoon, PO\(_4\) values appeared to be higher as the normal concentration of this nutrient recorded was only up to 0.04 mg l\(^{-1}\) in some of the lagoons in Mauritius (MFMR, 1998). The higher level of phosphate may be attributed to the input of freshwater as evidenced by the lower salinity and pH at the stations in that part of the lagoon. The level of PO\(_4\) > 0.04 mg l\(^{-1}\) is a matter of concern in relation to the health of the corals of a region (Connel and Hawker, 1991 as cited in MFMR, 1998).

The study indicates that the current pattern in the Flic en Flac lagoon is complex. Almost from the mid-length of the lagoon, the current close to the shore indicated a divergent flow pattern; the drogue movement was observed both in northerly and southerly directions changing course in the opposite directions (Figure 1). However, close to the reef, the flow of the current was always towards the passes. Further, the velocity of current in Flic en Flac lagoon is weak (0.01 - 0.31 ms\(^{-1}\)) with little tidal influence. Though a similar weak current has been observed in the lagoon at Albion (Chineah et al.
1999), the current pattern in Flic en Flac is different from the Albion lagoon where irrespective of the tides, the flow of current is always from north to south. Present study indicates that the seawater input in the system is limited and is mainly over reef top due to wave action and drains out through passes.

Corals in Mauritius display greater species diversity with 90 identified species and the true number certainly would be higher (MFMR, 1998). While the lagoon in Albion supports 20 species of corals (Chineah et al., 1999), in the present study only 9 species were observed with dominance of the branching corals such as A. muricata and A. intermedia. The substrate cover in various zones indicates that the near shore and midlagoon zones are dominated by sand whereas sand was totally absent in forereef zone. Highest percentage of live corals was recorded in the forereef zone and in the backreef macroalgae were dominant. The total absence of sand in the forereef zone shows that this zone is free from siltation. An estimate of mass bleaching of corals during March 1998 on the reef flats at Flic en Flac indicated 55.5 % of corals to bleach partially and 14 % of corals to bleach completely. This coupled with the very conservative species number observed in the area warrants an expanded study for understanding the coral species diversity in the lagoon.

The life in the marine and brackishwater animals is highly influenced by salinity and temperature as temperature can modify the effects of salinity and change the salinity range of the organism, and salinity can modify the effects of temperature (Wickgren, 1953; Smith, 1957; Verwey, 1957 and Kinne 1964; Srikrishnadhas et al. 1981). Hence, in the estuarine and coastal waters, the changes in temperature and salinity determine the distribution pattern of the organisms and the nature of substratum also plays an important role in the distribution of benthos (Srikrishnadhas et al., 1981). In the present study, though the changes in temperature were wide (23.0°C - 29.0°C), salinity had a narrow fluctuation (34.3 ‰ - 35.3 ‰) in the lagoon water at Flic en Flac. Hence, it may be inferred that the nature of the substratum and temperature to some extent would act as the limiting factors for the distribution of benthos.

Several factors have been attributed for the successful settlement and metamorphosis of pelagic larvae of benthic invertebrates, such as nature of the substratum, particle size, colour and light intensity, presence of compounds of inorganic and organic nature, the presence of bactero-algal film and the presence of colonies of their own species (Kiseleva, 1967). It is reasonable to infer that some of the factors stated above would influence the larval settlement and distribution pattern of the corals and echinoderms in the Flic en Flac lagoon.

Sea cucumbers and sea urchins show some zonal preferences by the species. While, the sea cucumber Bohadschia sp preferred coastal zone, S. chloronotus preferred midlagoon zone and the sea urchin distribution showed the preference of coastal zone < midlagoon zone < backreef zone in that order (Figure 4).

In the Albion lagoon 87 species of fishes have been reported (Chineah et al. 1999). In the present study similar to corals, the fish fauna is also less diverse. The presence of dense bed of seagrass in the midlagoon area would play a vital role in the distribution of the fishes. Of the 28 species recorded in the present study, the majority of them were smaller sized juveniles indicating that the seagrass patches act as nursery ground, for the fish (Costa et al., 1994).

Faecal pollution in recreational waters is responsible for several health hazards (Moe, 1997). The guideline limits for the coastal recreational waters of Mauritius are for TC < 1000 CFU / 100ml of water and for FC < 200 CFU / 100ml of water (GOM, 1999). The populations of TC an FC were well within the guideline limits during the study; however, there was no consistency in the distribution during different months in various stations in the Flie en Flac lagoon. Higher values were recorded during October and December 1999, and March and August 2000 than the other months. Analysis of variance indicated significant differences in the populations of TC between the months both in 1999 (P < 0.05) and in 2000 (P < 0.05). Similarly, significant difference in the values of FC between months both in 1999 (P < 0.05) and in 2000 (P < 0.05) was evident. However, no significant variations were found between the stations and years for both TC and FC values. Considering the die-off rates of terrestrial origin coliforms in salt water (Borrego et al., 1983; EPA, 1993; Rheinheimer, 1992) and their low levels recorded in Flic en Flac indicate that the water quality in the entire stretch of the Flic en Flac lagoon meets the bacterial standards prescribed and is safe for primary and secondary contact. However, it is also to be noted that the 200FC limit for 100 ml of coastal water would cause illness in 1.9 % of the swimmers (USEPA, 1986).
CONCLUSION

From the salient findings of the study in the lagoon at Flic en Flac, it may be concluded that

1. The water quality parameters are relatively stable.
2. Current in the lagoon is weak and complex.
3. Public beach is safe in terms of levels of coliform indicators for recreational activities.
4. Cover and species diversity of coral is low in the lagoon.
5. Cover of macroalgae and density of sea urchins is high in the backreef.
6. Fish faunal diversity in the lagoon is limited.

ACKNOWLEDGEMENTS

The authors are thankful to the Ministry of Fisheries, Government of Mauritius for the facilities provided and to the Chief Fisheries officer, Albion Fisheries Research Centre for his interest and critically going through the manuscript.

REFERENCES


OVERVIEW OF AN EXPERIMENTAL RELEASE METHOD OF THE SILVER SEA BREAM IN THE LAGOON AT ALBION (PETITE RIVIÈRE BAY)

S Khadun, R Hassea, T Shimizu and H Iwamoto
Albion Fisheries Research Centre

ABSTRACT
A programme to follow the movement pattern of marked sea bream in the lagoon at Albion was undertaken under Coastal Resources and Environment Conservation Project, with the assistance of JICA. Fish were marked by branding and were released in selected sites in the lagoon and off lagoon. Six batches with markings on different parts of the body were liberated from 1998 to 2000. Three areas of the lagoon were chosen for sampling purposes by seine nets. Marked sea bream were mostly captured from three areas. Information collected from amateur and net fishermen showed that marked fish were being caught in different area of the lagoon and the sea at Pointe Moyenne. The ecology of areas where marked sea bream had been captured should be studied. The release experiment has proved to be successful but trial on larger scale should be carried out to assess effectiveness of release. New method of marking should be tested and applied. Mauritius is the first country in the world where experiment on release of the Rhabdosargus sarba is undertaken.

Keywords: Sea bream, marking, movement pattern, recapture, restocking of lagoon, fishermen community

INTRODUCTION
The silver sea bream, Rhabdosargus sarba, is an important marine fish species in Mauritius. This species is widely distributed throughout the island and has been reported in many areas of brackish water. It is a first cluster group fish and is highly appreciated due to its white flesh and very good taste. It is mostly fished by artisanal fishermen in the lagoon as well as off lagoon around Mauritius. The Albion Fisheries Research Centre (AFRC) with the assistance of the Japan International Cooperation Agency (JICA) started release trial of this species under the Coastal Resources and Environment Conservation Project, which is a five-year programme. The main objective was to follow the movement pattern of fish after their release. Prior to the start of the experiment the marking method was selected and tested at the Centre for a few months. After which, the trial started in December 1998 with the liberation of some 1 300 sea bream. The lagoon at Albion, Petite Rivière Bay was chosen for that purpose, as sea bream catch has not been reported and as it is near the Centre, it is easier to monitor the trial. It is to be noted that Mauritius is the first country in the world where experiment on release of the Rhabdosargus sarba is undertaken. The potential to propagate the silver sea bream will be assessed at a later stage. Fish were liberated in six batches, four in the lagoon and two off lagoon.

MATERIALS AND METHODS

General
All fish were produced in the hatchery at AFRC in tanks during the winter, which is spawning season of the sea bream. Fish of different sizes were used for trial due to unavailability of a constant size batch. At the beginning of the experiment, bigger size fish were released.

Marking
In order to follow the movement pattern, marking or tagging of the released species is required. Marking is also a convenient method to distinguish between the hatchery reared fish and those from the wild. From 1998 to 2000 four batches consisting of some 6 600 sea bream were branded in selected parts of the body by using a hot iron rod. Marking at chosen parts will enable identification of the...
different batches. The branding method of marking is performed at a minimum cost. Marking has been carried out as follows:

a) the left side below the dorsal fin \((L)\)
b) the right side below the dorsal fin \((R)\)
c) the left side below the dorsal fin on the posterior side \((LPD)\)
d) the left side below the dorsal fin and at the caudal fin \((LDC)\)
e) the right side below the dorsal fin and at the caudal fin \((RDC)\)
f) the right side below the dorsal fin on the posterior side \((RPD)\)

After marking fish are kept in tanks containing 0.1 ppt of sodium nifurstyrate (Na-NFS) as a prophylactic treatment for one hour. The fish are stocked in a floating cage for more than two weeks to let the fish recover from marked wound. This method is quite effective as fish mortality is less than 5 % and the fish is not stressed. However fish should be above 10 cm in length.

The marked areas on the fish body after healing are covered again covered with scales. However, a patch is a clearly visible. Scales from these patches were removed and examined. It was found that all the scales are different in shape when compared to unmarked areas of the fish body.

**Size of marked sea bream**

The average total length and average body weight together with the respective length and weight ranges of the released marked sea breams for the five batches are shown in Table 1.

<table>
<thead>
<tr>
<th>Mark</th>
<th>Year</th>
<th>No.</th>
<th>Weight g</th>
<th>Length mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>L</td>
<td>1998</td>
<td>1300</td>
<td>50 - 190</td>
<td>115.2</td>
</tr>
<tr>
<td>R</td>
<td></td>
<td>1700</td>
<td>145 - 184</td>
<td>106.4</td>
</tr>
<tr>
<td>LDC</td>
<td>1999</td>
<td>200</td>
<td>53 - 169</td>
<td>95.0</td>
</tr>
<tr>
<td>RDC</td>
<td></td>
<td>300</td>
<td>76 - 301</td>
<td>189.0</td>
</tr>
<tr>
<td>LPD</td>
<td></td>
<td>525</td>
<td>16 - 130</td>
<td>55.4</td>
</tr>
<tr>
<td>RPD</td>
<td>2000</td>
<td>850</td>
<td>38 - 124</td>
<td>65.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>4875</td>
<td>16 - 301</td>
<td>100.7</td>
</tr>
</tbody>
</table>

**Transfer of fish to the lagoon**

One or two days before a release is executed, the fish are starved to avoid deterioration in water quality during transportation. Fish are carried by truck in one-ton plastic tank. Water in the tank is aerated during the whole trip. Fish are removed by plastic buckets and transferred to the sea or in a small floating cage when released off lagoon. The floating cage is slowly towed to the selected release site by a motorboat. Due precautions are taken during this operation to avoid rupture of the cage net by corals. The advantages of using a floating cage are as follows:

i. The fish are less stressed and acclimatized gradually to the new environment while being dragged to the release site.

ii. They received dissolved oxygen directly from the water instead,

iii. Liberation of the fish is made easy by untying the net only, thus avoiding further stress by handling

**Under water observation**

Immediately after liberation the behaviour of the fish in relation to its new surroundings is observed under water for a few hours. The bottom conditions are studied and the presence of predators such as caranx and barracuda, which is an inhibiting factor to the release program, is observed. The fish
usually stay in one group and move in a circle at the release point for some hours after which they move to different areas inside and outside the lagoon.

Collection of data

Data and other information on the released fish are collected from amateur fishermen, basket trap fishermen, and net fisheries, off lagoon fishermen and by seining operation carried out by our staff and nurserymen.

Physical parameters

Physical parameters like temperature and salinity are recorded during seining, which is performed randomly. These parameters will be needed to study any relationship of the released fish to its new environment in the future.

Seining in selected areas

Seining is undertaken in previously selected sites. These areas have been preferred because it can be easily seined. Three different areas of the lagoon have been chosen. The three areas opted for, are the barachois at Albion, the mouth of the Belle Eau River and the right side of the Albion lagoon and were named area 1, 2 and 3 respectively. All sea breams caught during seining, are sampled for length and weight parameters. Stocking effectiveness will also be assessed by this operation but at a later stage of the programme.

Result of seining operations

Sampling was performed on a monthly basis and was also related to the availability of nurserymen for seining operations. More sea breams were caught from the barachois. Results are shown in Table 2.

OBSERVATION

Twenty three seining operations were effected in 1999 and twenty two in 2000. Some 114 released sea breams were caught, 53 in 1999 and 61 until November 2000. From our seining operations, more fish were caught in the barachois at Albion where the water is brackish in nature than the right side of the Albion lagoon and consisted of fish with the six different markings. This indicates that irrespective of the site the fish are liberated, they will gather in the lagoon and barachois. All fish were released again after sampling. The ecology of both areas is different. These areas were surveyed and it the presence of different species of bivalves and gastropods in sufficient amount to attract sea breams was observed. However, from information gathered a large number of released sea bream were caught from the left side of the lagoon by amateur line fishermen and the right side the lagoon by amateur line fishermen as well as professional net fishermen. A small number of fish have also been reported from line fishermen from one area of the open sea at Pointe Moyenne.

DISCUSSION

At first, we have been relying more on data collected during our seining operations. We have assumed that the released sea bream do not move too far away from the release sites. As more marked sea bream has been captured in the barachois than the Petite Rivière bay, it is believed that the sea bream have a preference for brackish water. However, from the latest information collected from amateur fishermen, released sea bream are being caught near Pointe Moyenne some 5 km away from the Albion lagoon. This is showing that the released fish are wandering into new areas of the natural environment. During seining operations the ecology of sites, where fish have been caught, are different in terms of flora and fauna and bottom conditions. The ecology of these areas needs to be investigated to understand the behaviour of released fish. We are presuming that more than 90% of our first two
batches of released fish have already been caught by amateur and net fishermen, hence the small number of fish caught by our team during sampling exercises.

Table 2  Number of sea bream caught and number of seinings effected in 1999 and 2000

<table>
<thead>
<tr>
<th>Month</th>
<th>Seinings</th>
<th>Number caught</th>
<th>Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1999</td>
<td>2000</td>
<td>1999</td>
</tr>
<tr>
<td>Jan</td>
<td>4</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Feb</td>
<td>6</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Apr</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>3</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Jun</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>3</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Sep</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Oct</td>
<td>6</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>Nov</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Dec</td>
<td>8</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>22</td>
<td>53</td>
</tr>
</tbody>
</table>

Results obtained so far from preliminary data are satisfactory. The effect of release has proved to be successful. However, we should now carry out trial with smaller size fish. Sea breams should be liberated in small batches, in order not to aggregate fish after release. Such action may render capture of fish difficult for line and net fishermen. Moreover, fish should be properly adapted to the lagoon conditions prior to release. A fish pen could be set up in the estuary and lagoon for adapting fish before release.

The fishermen, local community and the public at large have to be involved in any restocking programme. Seminars and workshops has to be organized for fishers so as to inform them of this activity and the success it achieved in other countries.

CONCLUSION

This trial is aiming at the restocking of the lagoon as presently practiced in many countries. A long-term programme is required to assess its effectiveness and viability. However, the programme is dependent on the progress of the hatchery at Albion. More improvement in seed and juvenile production techniques is necessary in order to carry out large-scale releases. New marking methods such as elastomere paint and coded wire are needed to assess release effectiveness. Trials to condition fish to release situations are needed. The relation between fish size and time of release is to be investigated to increase rate of recovery and recruitment. More experiments on liberation need to be effected in areas around the island to evaluate their potential as site for stock enhancement. The fishermen community at large will be benefited by such projects.

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RELEASE OF MARKED SILVER SEA BREAM, *Rhabdosargus sarba*, IN AN ARTIFICIAL HABITAT AT THE MONTAGU BARACHOIS

*R Hassea, S Khadun, T Shimizu, H Iwamoto* and *R Sano*

Albion Fisheries Research Centre

**ABSTRACT**

Release experiment of marked silver sea bream *Rhabdosargus sarba*, (Forsskål 1775), reared in captivity, was carried out at the Montagu barachois in an artificial habitat, to evaluate the stocking effectiveness and movement pattern of the released and marked silver bream. This trial was carried out for a period of 32 days. The marked sea bream did not respond to the artificial device, they were rather dispersed in small school of 50 to 60 individuals at specific location of low salinity.

**Keywords:** Resource propagation, artificial habitat, barachois, aggregate.

**INTRODUCTION**

Silver sea bream (local name “gueule pavée”) is a carnivorous, euryhaline species which belongs to the family sparidae. The fish is widely distributed in the coastal inshore waters of Mauritius, mainly in the south east coast. It is considered as an excellent food fish and commands a high price on the local market (H. Bhudoye and Ishibashi 1998). Resource Propagation Program started in August 1997 under the five year activity program. It involves the liberation of hatchery produced and pond cultured silver sea bream fingerlings in the natural environment. This program consisted of marking, release, recapture and evaluation. Release program was effected both in the lagoon and in the barachois. Release of marked sea bream was also conducted from 1998 to 1999 at the Melville barachois and in the lagoon at Albion. Release of marked sea bream in the lagoon of Albion (R. Hassea et al. 1999a, 1999b) is still being monitored. Stocking effectiveness at the Melville barachois, was not successful because the fish escape in the lagoon due to the poor condition of the gridded gate. However, a new experiment of released and marked silver sea bream was carried out in an artificial habitat at the Montagu barachois. The purpose of setting up the artificial device was to attract and aggregate the released fish to the new environment. Supplementary feed was also given at a fixed point in the artificial habitat so as to attract the fish to this new environment.

**MATERIALS AND METHOD**

**Release site**

The Montagu barachois is a private owned barachois which is located on the east coast of Mauritius (*Figure 1*). It has an area of about 8 acres and the water body is densely surrounded with mangrove trees. A site was selected for setting up the artificial habitat. It was located almost near the centre of the barachois at some 100m away from the water entrance. Water exchange in the barachois is effected mainly by tidal fluctuation through sluice gates and big pipes which are linked to the lagoon. Water depth in the barachois varies between 1.0 to 3.0 m with a muddy and silty bottom condition (S. Khadun and C.R. Samboo 1999).

**Artificial habitat**

The artificial habitat consisted of a floating frame made of foam of dimension 4x4m. Ropes were attached longitudinally and transversely to the four side of the floating frame forming a quadrat like structure. Some 120 mangrove branches of about 1 m in height, were submerged and attached to the ropes using bending wire. A sheet of black “Sarlon” (5x5 m) was placed above the branches to create a...
shaded condition in the habitat. This condition was presumed to be favourable to aggregate the released silver sea bream.

**Released Fish**

Some 2000 marked silver sea bream of average body weight 55.4g (16–130g) and body length of 113.3 mm (75.5–146.3mm) were released around the artificial habitat (**Table 3**). The fish were produced in the hatchery from June to October 1998. The fish were marked by branding them using a hot iron rod on the left side below the dorsal fin. The marked sea bream were starved for at least one day in order to avoid water quality deterioration during transportation to the release site. The marked fish were removed from the floating cage at AFRC pond and placed in a one ton capacity tank for onward transfer to the Montagu barachois. The fish were disinfected with Sodium nifustyrenate (NFS-Na) at a dosage of 0.1 ppm as prophylatic treatment.

At the barachois the fish were transferred in a mobile floating cage and dragged by an outboard motor boat to the release site. The mobile floating cage was specifically designed and mounted for carrying the marked silver sea bream to the released site. The cage dimension was 1x1x1.5m, and the net mesh size was 1.5 mm. The cage was fixed on two floats and supported with two iron rods on both sides. Prior to releasing, the fish were stocked and acclimatized in a floating cage of dimension 4x4x2 m of mesh size 15 mm which was mounted next to the artificial habitat. The fish were fed with sea bream pellets at the rate of 10% bodyweight once daily. After 8 days, the floating cage was opened from below and all the fish were released around the artificial habitat.

**OBSERVATIONS**

The monitoring parameters were recorded on a regular basis. Physical and chemical parameters such as temperature, salinity, pH, water color, transparency, cloud percentage and wind velocity were recorded at the site of release. Five stations were selected to monitor temperature, salinity, pH, water color, transparency. The release point of the marked sea bream in the artificial habitat and the monitoring stations are shown in **Figure 1**.

Prior to releasing, the fish were hooked below their dorsal fin and were attached with a fine thread of nylon having a rounded and coloured float of 15 mm diameter at its extremity. Afterwards the fish were individually released so as to observe their movement behaviour.

**Seining**

After 22 days, a seining operation, for the recapture of the marked silver sea bream was carried out to evaluate the movement pattern, and recapture rate of this species. Seining was performed by a workforce of 8 persons using a net of 300 m, of mesh size varying between 10–15 mm. Four seining operations were undertaken, along the periphery of the barachois at locations 1, 2, 3, and 4 as shown in **Figure 1**. After each seining exercise, the recaptured silver sea bream (marked and unmarked) were sorted from other species using a dip net. They were further transferred in a bucket in order to record their growth.

**Collection of plankton samples**

Plankton samples were collected using plankton net (XX 13) around artificial habitat. The samples were fixed with formalin for identification under the microscope.

**RESULTS**

This experiment started on 3/09/99 (0 day) and ended on 23/10/99. The monitoring of different parameters are shown in **Tables 1** and **2**. The average water temperature, salinity and pH in the artificial habitat were 23.4 °C (21.6–25.1 °C), 18.8 ppt (14–25) and 8.1 (7.7–8.4) respectively.
The average temperature and salinity and pH at Point S and station C which were quite close to each other ranged from 22.4 °C (21.7–23.6 °C), 13.3 ppt (6–25 ppt), and 8.0 (7.9–8.3).

Collection of data on water condition was carried out at five selected stations as shown in Table 2. The mean temperature, salinity and pH at the five stations were 25.3 °C (24–26.9), 17.6 ppt (6–28) and 8.0 (7.8–8.3) respectively. The mean visibility of the water in the habitat was 2.5 m (2–3 m) while that at the five selected stations averaged at 1.42 m (1–2.7 m) against an average depth of 1.7 m. The bottom condition at the five selected stations in the barachois consisted of sand, gravel, rocks and small corals as shown in Table 2.

**Figure 1** The Montagu barachois

![Image of the Montagu barachois](image)

Neither mortality nor injuries were observed during stocking, but still the fish showed some sign of stress mainly because of crowding, handling, transportation and immediate transfer to the new environment.
A total of 25 silver sea bream, comprising of 16 marked and 9 not marked were recaptured after 4 successive seining operations, representing a catch of 0.8% as shown in Table 4. The marked silver sea bream were of average body length of 153.3 mm (129.5–176.8mm), average total length of 183.6 mm (116.9–210 mm) and an average body weight of 114.1g (62–164g). The mark endorsed below the dorsal fin was also checked and it was observed that the branded area was healing. The marked fish were thereafter released back in the barachois.

The unmarked silver sea bream were of average body length of 181.9 mm (123.4–247.2 mm) and average total length of 227.4 mm (153–305.1mm) and an average body weight of 237.3g (58–424g) as given in Table 3.

A catch of 3 and 12 marked silver sea bream resulted at location 1 and 4, this was comparatively higher than other seining sites.

The individual released fish immediately after liberation entered the artificial habitat but after sometime they were detached from the nylon thread, carrying away the hook. Few marked silver sea bream were observed under the artificial device after release, but most of them were dispersed. A school of 20 to 50 marked silver sea bream were regularly observed at Point S, at the end of the barachois as illustrated in Figure 1 and few individuals were found among the mangrove roots.

Underwater observations were carried out immediately after release of all the marked fish. The bottom condition at the release site was muddy and silty, resulting in a poor visibility. Monodactylus argenteus (Lune), Acanthuridae sp (surgeons fish) and Caranx sp. were often attracted and aggregated among branches of the artificial habitat especially when feed was applied.
After microscopic investigation of the water and plankton samples, three species of copepods (*Acartia* sp., *Oithona* sp. and *Microsetella* sp.) and nauplii, nematodes, polychaete, young bivalves, amphipoda and nauplii and blue green algae were observed.

Table 2 Recording of parameters at the five stations

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Stations</th>
<th>Temperature ºC</th>
<th>pH</th>
<th>Salinity ppt</th>
<th>Transparency m</th>
<th>Water colour</th>
<th>Bottom condition</th>
<th>Depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-Sep-99</td>
<td>12:15</td>
<td>A</td>
<td>24.10</td>
<td>7.8</td>
<td>11</td>
<td>1.2</td>
<td>13</td>
<td>R/Sty</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>12:20</td>
<td>B</td>
<td>21.80</td>
<td>8.1</td>
<td>6</td>
<td>2.7</td>
<td>13</td>
<td>M</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>12:25</td>
<td>C</td>
<td>21.70</td>
<td>8.0</td>
<td>6</td>
<td>1.0</td>
<td>12</td>
<td>R/Sdy</td>
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</tr>
<tr>
<td></td>
<td>12:30</td>
<td>D</td>
<td>24.30</td>
<td>7.8</td>
<td>12</td>
<td>1.0</td>
<td>14</td>
<td>G/Sdy/Sty</td>
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</tr>
<tr>
<td></td>
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<td>E</td>
<td>23.60</td>
<td>7.8</td>
<td>21</td>
<td>1.5</td>
<td>13</td>
<td>R/Sdy</td>
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</tr>
<tr>
<td></td>
<td>10:48</td>
<td>F</td>
<td>24.20</td>
<td>8.0</td>
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<td>R/Sdy</td>
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<tr>
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<td>10:07</td>
<td>A</td>
<td>21.90</td>
<td>8.1</td>
<td>21</td>
<td>1.0</td>
<td>13</td>
<td>R/Sdy</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>10:02</td>
<td>B</td>
<td>22.30</td>
<td>8.3</td>
<td>20</td>
<td>2.5</td>
<td>13</td>
<td>M</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>10:21</td>
<td>C</td>
<td>21.90</td>
<td>7.9</td>
<td>25</td>
<td>1.0</td>
<td>14</td>
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<td></td>
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<td>1.0</td>
<td>14</td>
<td>G/Sdy/Sty</td>
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<td>28</td>
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<td>13</td>
<td>R/Sdy</td>
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</table>

M-Muddy, R/Sty –Rocky/Silty, R/Sdy –Rocky/Sandy, G/Sdy/Sty –Gravel/Sandy/Silty, R/Sdy/Sty –Rocky/Sandy/Silty

Table 3 Weight and length of the released and marked silver sea bream at stocking and recapture

<table>
<thead>
<tr>
<th>Date</th>
<th>Standard body length</th>
<th>Total body length</th>
<th>Body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>g</td>
</tr>
<tr>
<td>Release</td>
<td>3-Sep-99</td>
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<tr>
<td></td>
<td>113.3</td>
<td>138.9</td>
<td>55.4</td>
</tr>
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<td></td>
<td>75.5 - 146.3</td>
<td>96.2 - 181.3</td>
<td>16 - 130</td>
</tr>
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<td></td>
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<td></td>
<td>153.3</td>
<td>183.6</td>
<td>114.1</td>
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<tr>
<td></td>
<td>129.5 - 176.8</td>
<td>116.9 - 210.0</td>
<td>62 - 164</td>
</tr>
</tbody>
</table>
Table 4 Recapture result of silver sea bream on the 23 September 99

<table>
<thead>
<tr>
<th>Site no</th>
<th>Body Length</th>
<th>Total Length</th>
<th>Body Weight</th>
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<tr>
<td></td>
<td>mm</td>
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<tr>
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<td></td>
<td>154.2</td>
<td>195.5</td>
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<tr>
<td></td>
<td>145.1</td>
<td>188.2</td>
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<td>2</td>
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<td>305.1</td>
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<tr>
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<td>195.0</td>
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<td>152</td>
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<td></td>
<td>176.8</td>
<td>210.0</td>
<td>164</td>
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<td></td>
<td>166.0</td>
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<td>127.5</td>
<td>154.5</td>
<td>70</td>
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<tr>
<td></td>
<td>205.3</td>
<td>267.1</td>
<td>328</td>
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<tr>
<td></td>
<td>228.3</td>
<td>282.5</td>
<td>398</td>
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<td></td>
<td>212.0</td>
<td>267.9</td>
<td>336</td>
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<td></td>
<td>218.9</td>
<td>268.2</td>
<td>334</td>
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<tr>
<td></td>
<td>130.1</td>
<td>160.5</td>
<td>76</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

The released and marked silver sea bream did not show any response to the artificial structure although daily feeding was carried out. They were dispersed throughout the barachois, but sometimes were concentrated in specific habitat where salinity was low as compared in the artificial habitat. The presence of silver sea bream at the Point S and at seining site 1 at harvest clearly indicated their preference to brackish water. Generally, silver sea bream live close to the shoreline and usually feed on mollusks and crustacean with their strong teeth (D. King 1996). Young fish inhabits in estuaries as nurseries in Natal and further north (J. L. B. Smith and M. M. Smith 1986). According to Hassea et. al. (1999b), silver sea bream previously released in the lagoon (high salinity) were recaptured in river mouth and in the barachois (brackish areas of low water salinity).

Monodactylus sp. (Linneaus 1758) was regularly observed in the artificial habitat. This species are present mainly in large coastal estuaries in silty habitats, or often in large schools around break waters or under jetties. Fingerlings from the brackish water, sometimes move to fresh water (H. Debelius 1993, R. H. Kuiter and H. Debelius 1994). This fish has a small mouth; jaws with band of tiny conical teeth which feed on planktons and detritus. It was observed that this species, were attracted due to the presence and accumulation of plankton on branches of the artificial habitat. Such behaviour clearly indicates that this species responded to the artificial device and it could be considered as a responding candidate for this type of stocking.

The bottom conditions at the artificial habitat were muddy and silty. The submerged mangrove branches were only midway to the floor of the barachois, thus, were unable to serve as a shelter to the
silver sea bream. This condition might be inappropriate and unfavourable for rearing of silver sea bream as this species is a bottom-living coastal fish. The silver sea bream were rather observed in areas where the bottom condition consisted of sand, gravels, rocks and corals (Point S and station C, Figure1).

The recapture rate was low, representing a catch of only 0.8%. This was attributed due to the vastness of the barachois and limited seining operation. Seining was carried out at selected sites because of the rocky nature at the bottom of the pond at certain locations. Other gears such as basket trap or cast net are recommended to be used in future for the recapture exercise.

ACKNOWLEDGMENTS

We acknowledge with thanks the advice of Messrs. C. R. Samboo, Divisional Scientific Officer, Dr. H. Terasima JICA expert and all staff of the Aquaculture Division of AFRC.

We also express our gratitude to the owner of the Montagu barachois for his support in allowing us to carry out the experiment.

We are also grateful to the nurserymen team for their valuable input throughout this experimental exercise.

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HASSEA R., KHADUN S, IWAMOTO H and SHIMIZU T. 1999b. Recapture of marked sea bream (Rhabdosargus sarba) in the lagoon of Albion and in the barachois, Albion Fisheries Research Centre (unpublished).


RESPONSE TO UREA MOLASSES MULTI NUTRIENT BLOCKS AS A SUPPLEMENT IN THE DIET OF GOATS

D Saddul and A A Boodoo

Agricultural Research and Extension

ABSTRACT

Urea molasses multinutrient blocks (UMMB) in small ruminant diet have been used in many countries, but this technology is new in Mauritius. Trials have been conducted on two government farms to obtain data on the response of goats (does and weaned kids) to this feed in terms of intake and liveweight gain when used in combination with a dairy concentrate or cottonseed cake. Average daily intake of UMMB by does was 216 g d⁻¹, while for the weaners it was 152 and 166 g h⁻¹d⁻¹ for the two farms. Better response was obtained with weaners when fed UMMB in combination with cottonseed cake as compared to the dairy concentrate. No signs of toxicity due to urea were observed and the feed can be recommended for use by the smallholder goat farmers.

Keywords: urea molasses multinutrient blocks, goats, daily intake, supplement, toxicity.

INTRODUCTION

Goats in the villages are reared traditionally on a forage-based diet and the practice of supplementation is not common. This traditional feeding system is insufficient to satisfy the nutritional needs of the goats, particularly during high production periods like late pregnancy, lactation and growth. It results in poor growth performance of the kids, particularly in multiple litters, giving low live weights at 90 days of age with wide variations from 5kg to 10kg for the local breed, as well as a high kid mortality of 16% during the first three months of life (Saddul et al 1999).

Urea molasses multinutrient blocks (UMMB) provide a readily available source of energy in the form of molasses, nitrogen (both from protein and non-protein sources), fibre and minerals. Hadjipanayiotou (1996) reported that molasses-urea blocks have been successfully used in different parts of the world. However, its use as a supplement to the basal forage diet of goats in Mauritius is new.

Trials have been conducted to obtain data on the intake of UMMB by goats and on its effects when used in combination with cowfeed (a dairy concentrate of 17% crude protein) or cottonseed cake.

Objective

To monitor the intake of UMMB by pregnant does and weaned kids and to evaluate the performance of the weaned kids when fed UMMB in combination with cowfeed or cottonseed cake.

Methodology

Trials were conducted on does as from the early stage of pregnancy at the Richelieu Prison farm and on weaned kids on the same farm and at the Curepipe Livestock Research Station (CLRS). On both farms, the animals were fed a basal diet of mixed fodder ad libitum. Sugar-cane tops were also fed during the harvest season. Water was provided ad libitum. All the animals were systematically treated for internal parasites. The goats were Boer/Anglo-Nubian crosses.

At the Prison farm

I. Pregnant does were allocated to three groups as follows:

Control: Cowfeed @ 450 g h⁻¹d⁻¹ (the normal practice on the farm)
Response to urea molasses multinutrient blocks as a supplement in the diet of goats.  

D Saddul and AA Boodoo.


246

Treatment 1: Cowfeed at 110 g h\(^{-1}\)d\(^{-1}\) plus molasses block ad libitum
Treatment 2: Cowfeed at 225 g h\(^{-1}\)d\(^{-1}\) plus molasses block ad libitum

The does were fed UMMB as from early pregnancy stage and were monitored till weaning of their kids for two consecutive kiddings.

II. 24 kids weaned at 90 days, were allocated randomly to control (5 males; 5 females) and treatment groups (7 males; 7 females), respectively. The kids were fed cowfeed at 300 g h\(^{-1}\)d\(^{-1}\) (control), while the treatment group received 300g cowfeed and UMMB ad libitum. They were monitored till breeding age (16 months of age).

At the Curepipe Livestock Research Station

5 male and 5 female kids weaned at 90 days were fed UMMB ad libitum in combination with cottonseed cake. Cottonseed cake was initially fed at 50 g h\(^{-1}\)d\(^{-1}\) and was gradually increased to 300 g h\(^{-1}\)d\(^{-1}\) and this level was maintained till one year of age.

On both farms, the animals were group fed and were weighed every fortnight. The UMMB was placed in wooden trays and the animals had free access to it. New UMMB was replaced whenever required. The goats were kept on litter and it was not possible to monitor fodder intake by the different groups.

RESULTS AND DISCUSSION

UMMB intake

Table 1 shows the intake in the different treatments.

<table>
<thead>
<tr>
<th>Does at Prison farm</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UMMB+cowfeed@</td>
<td>UMMB+cowfeed @</td>
</tr>
<tr>
<td></td>
<td>110 g h(^{-1})d(^{-1})</td>
<td>225 g h(^{-1})d(^{-1})</td>
</tr>
<tr>
<td>Number of does</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Average daily intake- over a 550-day period</td>
<td>266±9.0</td>
<td>313±16</td>
</tr>
</tbody>
</table>

Weaners at Prison Farm (UMMB +300g cowfeed)

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of heads</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Average UMMB intake- over a 368-day period</td>
<td>256±25</td>
<td>220±20</td>
</tr>
</tbody>
</table>

Weaners at CLRS (UMMB + 300g cottonseed cake)

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of heads</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Average UMMB intake</td>
<td>197±28</td>
<td>121±15</td>
</tr>
</tbody>
</table>

The average UMMB intake for weaners (sexes combined) at the Prison Farm and at CLRS was 234 and 169 g h\(^{-1}\)d\(^{-1}\), respectively. The mean final weight for the weaners in the treatments were 30 kg at the Prison farm and 33 kg at CLRS. This gives UMMB intake values of 800g and 500g/100kg liveweight,
respectively. This intake exceeds the value of 400g/100kg liveweight reported by Sansoucy et al (1988), and no signs of urea toxicity were observed. Data obtained in studies conducted on lambs and goats in different countries vary according to the basal diet fed but are in the range of 100-150g head \(^{-1}\) day\(^{-1}\).

**Liveweight gain**

Table 2 gives the liveweight gain on the two farms.

<table>
<thead>
<tr>
<th>Table 2 Liveweight gain of weaners at Prison Farm and CLRS.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Weaners at Prison Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>(UMMB + cowfeed at 300 g(^{-1})h(^{-1})d)</td>
</tr>
<tr>
<td>Males Females Males Females</td>
</tr>
<tr>
<td>Initial weight kg 15.5 ± 0.9* 11.6 ± 1.9 14.0 ± 1.2 13.1 ± 0.9</td>
</tr>
<tr>
<td>Final weight kg 29.5 ± 1.7 26.7 ± 3.3 30.0 ± 2.1 31.7 ± 1.2</td>
</tr>
<tr>
<td>Average daily gain(^{1}) g 35.0 ± 4.0 35.0 ± 4.0 48.0 ± 6.0 49.0 ± 9.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weaners at CLRS (UMMB + 300g cottonseed cake)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Males Females</td>
</tr>
<tr>
<td>Initial weight kg 14 ± 0.8 12.6 ± 0.8</td>
</tr>
<tr>
<td>Final weight kg 36.2 ± 0.7 30.7 ± 0.5</td>
</tr>
<tr>
<td>Average daily gain(^{2}) g 61.0 ± 4.0 50.0 ± 2.0</td>
</tr>
</tbody>
</table>

* Mean ± SE \(^{-1}\) over a 368-day period \(^{-2}\) over a 270-day period

There was no significant difference in liveweight gain between the treatment and control at the Prison Farm. The average daily liveweight gain for both treatments and sexes was 42 ± 4.0g. However, the weaners at CLRS showed better response with an average daily gain of 56 ± 4.0g day\(^{-1}\) to UMMB when used in combination with cottonseed cake and they had a lower UMMB intake (an average of 169g compared to 234g for weaners at the Prison farm).

**UMMB and feeding behaviour of the goats**

Goats tend to eat the UMMB by nibbling small bites, unlike cows which tend to lick the UMMB. At CLRS, kids in the pre-weaning stage consumed the UMMB in very small quantities and no signs of urea toxicity were observed. It is believed that this is due to their nibbling feeding behaviour.

At the Prison farm, UMMB intake was low during the 2 weeks of the adaptation period for the does and it increased gradually after a period of 3 to 6 weeks. For the weaners the low intake during adaptation lasted for 3 to 4 months, although the UMMB was fed *ad libitum*. The UMMB intake varied according to the quality of fodder provided. Thus intake tended to be higher when fodder was scarce and of poor quality.

**DISCUSSION**

These observations on the effect of UMMB on the performance of weaner goats are satisfactory in terms of both acceptance of the feed by the animal and growth rate when used in combination with cottonseed cake. No signs of urea toxicity have been observed even on kids under 3 months of age.

Thus UMMB can be safely recommended at the smallholder level where a mixed flock system of rearing prevails. Furthermore it provides a regular source of nutrients to the animal throughout the day and, hence, corrects for any deficiencies (Hadjipanayiotou et al, 1993). Studies conducted on sheep (Vargas and Riviera, 1994) showed that the provision of multi-nutritional block (10% urea, 50% molasses) *ad libitum* drastically reduced mortality in both ewes and lambs of African Hair breed. Furthermore, it has been shown that feeding of UMMB to ewes initiated early ovarian activity and
shortened the interval from parturition to conception (Vargas and Riviera, 1994). Smallholder goat farmers can thus be encouraged to use UMMB for better animal performance.

CONCLUSION

The UMMB is practical for use as it is easy to store and handle. It also avoids the routine of daily hand feeding. It can be recommended to goat farmers by virtue of its nutritive value and ease of use. Further investigations need to be carried out in the village goat farms to get more insight into the effect of UMMB on their reproductive and growth performance.

REFERENCES


INCREASING SMALLHOLDER MILK PRODUCTION THROUGH ADOPTION OF CONCENTRATE SUPPLEMENTATION AND THE HIGH ADOPTION RATE OF THE TECHNOLOGY

P Toolsee and AA Boodoo

Agricultural Research and Extension Unit

ABSTRACT

On farm studies to evaluate the benefits of concentrate supplementation on milk yield and reproductive efficiency of dairy cows were reviewed. Supplementing the basal diet with cotton seed cake and cowfeed (a dairy concentrate with 17% crude protein) increased milk production by 35-38% and 33-39% respectively. Milk production for the first 91 days of lactation represented around 40% of the total milk produced in the whole lactation. In a second trial supplementation with cotton seed cake increased milk production by 11-30%. However, there was no effect on resumption of ovarian activity and on calf birth weight. Records of sales figures of the Ministry of Agriculture show a high adoption of this supplementation technology among the smallholder dairy farmers.

Keywords: smallholder, concentrates, supplementation, resumption of ovarian activity, technology adoption.

INTRODUCTION

Dairy cattle owned by smallholders annually produce around 700 tonnes of fresh milk, equivalent to about 7% of our national consumption. Low quality roughage which is the basal diet in the village farming system is not sufficient for sustainable production. Supplementing the basal diet with concentrates is therefore essential to increase productivity. The benefits of supplementary feeding (lentils, pigeon peas, Leucaena seeds) for dairy cows at the smallholder level were first shown in 1956 by Bennie. On farm studies on a large scale were initiated in the late 1980’s to study the effect of concentrate feeding on the improvement of milk yield and reproductive efficiency of dairy cows. Two studies will be reviewed and their results discussed along with data on sale figures of concentrates.

MATERIALS AND METHODS

Experiment 1: Effect of supplementing (cowfeed:dairy concentrate, 17% crude protein) and cotton seed cake on milk production

An on-farm trial was initiated in 1985, in two regions, Vacoas (annual rainfall >2500 mm) and Mapou (annual rainfall 1250-2500 mm) to study the effect of supplementing cowfeed (a locally compounded concentrate having about 17% crude protein) and cotton seed cake (CSC) on milk yield. Cows that were 7 months pregnant were selected and were allocated alternately to each of two treatments. In each area 22 cows received each of the two supplements (cowfeed or CSC) during 3 months pre-calving and 10 months of lactation. The feeding regime was 2 kg cowfeed and 1 kg cotton seed cake respectively for pregnant animals during the last 2 months of pregnancy, and 0.5 kg cowfeed and 0.25 kg cotton seed cake for every litre of milk produced during lactation.

Mixed fodder and sugar cane tops collected by farmers from the neighbourhood were offered *ad libitum*. Sugar cane top is lower in crude protein (7.8%) than assorted fodder (11.8%). Cotton seed cake which is imported has 41.1% crude protein.
Experiment 2: Increasing milk production and reproductive efficiency of dairy cows through supplementation with cotton seed cake

Another on farm study was conducted during 1995-1997. Three different geographical sites were selected. They were the Bambous area (annual rainfall < 1250 mm), Rempart area (annual rainfall of 1250-2500 mm) and Henrietta area (annual rainfall > 2500 mm). Cows confirmed pregnant by rectal palpation were selected. Their body condition score (BCS) was determined at selection time and cows were allotted alternately to each of two treatments. In the first treatment, cotton seed cake was provided by the project, at the rate of 1 kg/d for about 5 weeks before expected calving date, 3 kg/d during the week after calving and 0.25 kg/L of milk produced thereafter. The cows also received 15g/d of a mineral mixture. In the second treatment (control) no cotton seed cake was given to the cows by the project. The farmers continued with their traditional practice of giving some cowfeed to their cows. In fact, in both treatments this practice was common. Milk samples (20 ml) were collected weekly as from 20 days after calving to determine the time of resumption of ovarian activity. The samples were analysed for progesterone level by the solid phase radioimmunoassay supplied by FAO/IAEA (Plaizier, 1993). During the sugar cane harvest season (July - December) cane tops were fed ad libitum together with mixed grasses. During the non-harvest season (January - June) mixed grasses and vegetable crop residues were fed.

RESULTS

Experiment 1

**Table 1** Milk production during the full 301 day lactation and for first 91 days of lactation for cows fed with two supplements. (Adapted from Boodoo et al. 1988)

<table>
<thead>
<tr>
<th></th>
<th>Vaccoas</th>
<th>Mapou</th>
<th>Significant level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cowfeed</td>
<td>CSC</td>
<td>Cowfeed</td>
</tr>
<tr>
<td>301 day lactation</td>
<td>3 023</td>
<td>2 871</td>
<td>2 538</td>
</tr>
<tr>
<td>SE ±</td>
<td>146</td>
<td>104</td>
<td>139</td>
</tr>
<tr>
<td>First 91 days</td>
<td>1 265</td>
<td>1 183</td>
<td>992</td>
</tr>
<tr>
<td>SE ±</td>
<td>50</td>
<td>34</td>
<td>48</td>
</tr>
</tbody>
</table>

*, ** P < 0.05 and 0.01, respectively. NS = Not significant

For the whole lactation period and for the first 91 days there was no difference between the two concentrate treatments in either area. However there was an area difference with regard to cowfeed, cows in the Vacoas region produced significantly more milk. Unsupplemented cows had a shorter lactation length, around 225 days, with a total milk yield of around 1012 kg.

Milk production for the first 91 days of lactation represented around 40 % of the total milk produced in the whole lactation. There was a positive correlation (r² = 0.86) between the average daily milk yield of the first 91 days and the total lactation yield. There was no significant difference regarding the lactation number between the treatment groups.

Experiment 2

The body condition score was measured on a scale of 1-5 and four monthly measurements were made after calving. There was no important change in BCS throughout the intervention period. The mean intake of cowfeed for both groups was 4.4 and 3.8 kg d⁻¹ for Bambous and Henrietta areas respectively. For Rempart region, the cows in the treatment group received 3.0 kg d⁻¹ of cowfeed while no data could be collected for the control group because of lack of cooperation on the part of the farmers.
Supplementation with cotton seed cake significantly increased milk production and cows in the Henrietta region gave the highest milk yield. The average birth weight of calves was 30.6 and 30.5 kg for control and treatment groups respectively in the Bambous region, and 38.1 and 38.7 kg for control and treatment groups in the Henrietta region. This suggested that supplementing with cotton seed cake prior to calving had no significant effect on calf birth weight in both regions. However, there was significant difference between the birth weight of calves in Bambous and Henrietta regions, Henrietta calves being heavier (38.1 and 38.7 kg) than Bambous calves (30.5 and 30.6 kg).

The intervals from calving to resumption of ovarian activity are shown in Table 3.

**DISCUSSION**

Cows in the wet region produced more milk than in the dry regions with either type of concentrate. In the first trial, supplementing the diet with cotton seed cake increased milk production by 35-38% while for cowfeed it was 33-39%. In the second trial supplementation with cotton seed cake increased milk production by 11-30%, and taking into account the price of cotton seed cake, this amounted to a 2:1 return and therefore was economical. It is also noted that half the amount of cotton seed cake, as

---

Table 2 Average daily milk production of cows ± Standard deviation (kg d⁻¹) from three regions over a period of 4 months after calving (Adapted from Boodoo et al. 1999).

<table>
<thead>
<tr>
<th>Regions</th>
<th>Months</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Bambous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>11.3 ± 1.9</td>
<td>11.1 ± 2.3</td>
</tr>
<tr>
<td>Observations</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Treatment</td>
<td>13.8 ± 1.7</td>
<td>13.8 ± 1.7</td>
</tr>
<tr>
<td>Observations</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Henrietta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>11.5 ± 3.1</td>
<td>12.5 ± 3.0</td>
</tr>
<tr>
<td>Observations</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Treatment</td>
<td>12.4 ± 2.6</td>
<td>13.7 ± 2.8</td>
</tr>
<tr>
<td>Observations</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Rempart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>11.0 ± 3.3</td>
<td>11.4 ± 2.0</td>
</tr>
<tr>
<td>Observations</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

Values with different superscripts in the same column are significantly different (P < 0.05)

Table 3 Mean interval ± SD (days) from calving to resumption of ovarian activity of cows (Adapted from Boodoo et al. 1999)

<table>
<thead>
<tr>
<th>Regions</th>
<th>Bambous</th>
<th>Henrietta</th>
<th>Rempart</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment</td>
<td>Control</td>
<td>Total</td>
</tr>
<tr>
<td>Number of cows</td>
<td>15</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Mean interval</td>
<td>111 ± 49</td>
<td>88 ± 21</td>
<td>103 a ± 41</td>
</tr>
<tr>
<td>Range</td>
<td>26 - 227</td>
<td>59 - 124</td>
<td>39 - 152</td>
</tr>
</tbody>
</table>

Values with different superscripts in the same row are significantly different (P < 0.05)

There were no significant difference between the treatment and control groups in the number of days from calving to resumption of ovarian activity. However, there was a significant difference (P<0.05) in the number of days from calving to resumption of ovarian activity of cows between the three regions, Bambous showing a longer interval than Henrietta or Rempart.
Increasing smallholder milk production through adoption of concentrate supplementation and the high adoption rate of the technology. P. Toolsee et al.

compared to cowfeed, was required to produce the same amount of milk. However, further supplementation with cotton seed cake (second trial) has not been able to show an effect on resumption of ovarian activity and on calf birth weight.

The farmer – research collaboration together with the support of related institutions in on-farm interventions and studies has had a very positive impact on the adoption of the supplementation technology. The survey results of Toolsee et al (1995) showed that the average consumption of concentrate was 2.2 kg day$^{-1}$ (1.3 - 3.0 kg d$^{-1}$). Around 95% of the farmers surveyed (250 farmers interviewed) used concentrates to feed pregnant and lactating cows while it was only 56% in 1968, as reported by Milliken.

Records of sales figures (at the Ministry of Agriculture) show that in 1975, with a cattle population of 42,500 head, 750 tonnes of cowfeed and none of CSC were purchased by the smallholders. In 1985, with a reduced cattle population of 25,485 head, the sale of cowfeed increased to 887 tonnes. In 1995, 129 tonnes of CSC were purchased. While in the year 1999 with a still smaller cattle population (9,500 head), 3740 tonnes of cowfeed and 277 tonnes of cotton seed cake were purchased by the farmers. These data show that in 1999, along with a reduction in cattle number to a quarter of what it was in 1975, the amount of cowfeed consumed increased five fold. Together with the 277 tonnes of CSC sold (more than twice the figure of 1995) this amounts to a tremendous success in technology adoption on the part of the smallholder farmers.

CONCLUSION

The evidence is conclusive that the smallholders have successfully adopted the practice of feeding concentrate to their cows. However, there is potential for a further increase in milk yield at the smallholder level if more farmers adopt concentrate supplementation and feed it at the recommended rate. More investigation is warranted to study the effect of supplementation on the reproductive efficiency of dairy cows.

REFERENCES


A SIMPLE PROCEDURE FOR STAINING THE BONES OF THE SILVER SEA BREAM, RHABDOSARGUS SARBA

Hans Bhudoye1, Hiromi, T Nakamura2, T Shimizu3 and H Iwamoto3.

Albion fisheries research centre

INTRODUCTION

The sea bream, Rhabdosargus sarba belongs to the family Sparidae and is commonly found in the coastal waters of Mauritius. Mass seed production of this species has been carried out at the Albion Fisheries Research Centre (AFRC) since 1989. Recently it was observed that many of the fries and fingerlings of the species to have bone deformation. For the observation of the bone structures alizarin staining technique as employed by Potthoff, T. 1984 was used with some modifications to stain the whole fish in order to observe the bone structure in situ. This staining technique will help in the bone study of the silver sea bream.

MATERIALS

Hatchery reared and pond raised 10 silver sea bream of 180 days old, weighing 10.8 g with a mean total body length of 88.5 mm were used for the staining experiment. They were tagged for ease of identification. Chemicals. The chemicals used for the staining procedure are listed below:

- Formaldehyde solution 40% (BDH-Limited Poole, England)
- 85% KOH (HiMedia. Laboratories Pvt. Limited, Mumbai (Bombay) India
- Alizarin red S (Wako Pure Chemical Industries Ltd, Japan)
- 99.5% Glycerol (Saarchem (PTY) Ltd, Republic of South Africa)

The 10% formalin was prepared by diluting 1 part of formaldehyde with 3 parts of distilled water (formalin is a 37-40% solution of formaldehyde). For the preparation of 5% KOH, 58.8 g of 85% KOH was dissolved in 1000 ml of distilled water. Alizarin red stain was prepared by dissolving 0.1 g of Alizarin red S powder in 100 ml of distilled water.

METHODS

Killing

Kill the fish by dipping them in ice-cold water for a few minutes.

Fixation

The fish were then fixed in 500 ml of 10% neutral formalin for over 24 hours. Washing

Before proceeding with the staining procedure, the specimens were washed thoroughly under running tap water for at least one hour to remove excess slime and formalin.

1 Albion Fisheries Research Centre (AFRC)
2 502,7-4 Maruyama, Kamifukuoka-shi, Saitama prefecture, JAPAN
3 Japan International Cooperation Agency (JICA)
Bone staining

Staining agents combine with tissues and improve the visibility of their components by imparting colour to them. The fish were then placed in a glass jar containing 1500 ml of 5% KOH. The staining solution containing 1% alizarin red S was added drop by drop to the freshly prepared 5% KOH solution holding the specimens till the medium (KOH) showed pinkish violet colour. About 15 ml of the staining solution was utilized.

Scaling

As the scales hinder the staining, they can now be removed only along the vertebrae by just rubbing back and forth the body surface of the fish with a fine forceps carefully. The specimens are transferred back to the staining medium for further bone staining again.

Removing excess stain

An attempt was also made to remove the excess stain in the specimen by holding them in 1000 ml of 4% KOH before transferring to glycerol containers.

Preservation

Depending upon the desired degree of staining, the specimens were either transferred directly to glycerol for clearing or kept again in freshly prepared staining medium. The specimens were observed daily. Final preservation was made in a glass bottle containing some 600 ml of fresh 99.5% glycerol with glass or rubber stoppers to which few crystals of thymol were added to prevent mold.

RESULTS AND DISCUSSION

The specimens took stain at different time intervals based on the duration of exposure to the staining medium. The bones stained bright red in almost all the specimens where the scales were removed. This shows that the scales act as a barrier in preventing the infiltration of the stain. Bone staining and clearing was effective in the specimens using the above method. The best result could be obtained in specimen No. 10 Figure 1. In this case the scales were removed just after keeping the fish in the staining medium initially for 2 days and again placing the scaleless fish in the medium for another 5 days for complete staining of the vertebrae. So from this experiment it appears that 7 days are sufficient for staining the vertebrae in silver sea bream fish of 8-10 cm size after removing the scales. This staining procedure is simple compared to the conventional methods. In the case of bigger size fish it is proposed to steam the fish first, thereby facilitating removal of scales, skin and flesh, leaving aside the bone structure intact. Another method to observe the bone structure is by X-ray, but it is costly compared to alizarin staining method. The present staining technique would be helpful in the basic osteological studies of fishes.

ACKNOWLEDGEMENTS

The author would like to extend his thanks to Dr. N. Jayabalan (ITEC-Expert in Fish Toxicity) Mr. C. R. Samboo and all the staff of Aquaculture division for their help and support. This paper was supported by JICA (Japan International Cooperation Agency) and the Albion Fisheries Research Centre(AFRC), Ministry of Fisheries and Cooperative.
A simple procedure for staining the bones of the silver sea bream, *Rhabdosargus sarba*  

Hans Bhudoye et al.

**Figure 1** Silver sea bream stained with alizarin red S (BL 8-10 cm)

REFERENCE

THE DECOMPOSITION RATE OF CATTLE MANURE IN THE TWO MAIN SOIL TYPES OF THE SEYCHELLES

K Nancy and J Loustau Lalanne

ABSTRACT

Cattle manure is widely used as organic fertiliser and soil ameliorant in the two main soil types of the Seychelles. Its rate of decomposition in both the acidic red earth and alkaline sandy coralline soil is of importance in order to gauge replenishment rates for sustained soil fertility. Both soil types have low fertility status and the level of Cation Exchange Capacity (C.E.C) and water holding capacity are dependant on the level of organic matter in the soil. A litter decay experiment was carried out on the research farm and results indicate that the decomposition rate is much higher in the sandy coralline soil than in the acidic red earth. This infers that farmers cultivating the sandy coralline soil have to increase the application rate of cattle manure.

INTRODUCTION

Cattle manure is usually applied at a rate of 20-30 t/ha (2 - 3 kg M⁻²) either incorporated during soil preparation or applied at the base of the planting hole. This method and rate of application is repeated with each new crop not taking into account the crop cycle and residual effects.

The rate of decomposition would therefore give an indication of replenishment rates of cattle manure.

MATERIALS AND METHODS

Sixteen (16) litter bags of 7 mm mesh were each filled with 1 kg of air dried cattle manure and buried to a depth of 15-20 cm in both soil types. Each month one bag was removed from each soil type, dried to constant weight and a final weight noted.

The percentage decomposition was calculated over time.

RESULTS AND DISCUSSION

Results show a significant difference in the decomposition rate of cattle manure in the two main soil types. Figure 1

The percentage decomposition is much higher in the sandy soil (12.37 %) than in the red earth. This is noticeable from the onset and sustain throughout the investigation. Granulometric analysis of the sandy soil (sieve method) gave a result of 98.37 % sand as compared to the red earth with 72.40 % sand and a higher silt and clay percentage. The physical property of the soil and its ability to retain moisture therefore has a bearing on the decomposition rate of organic matter.
CONCLUSIONS AND RECOMMENDATIONS

It can therefore be inferred that the replenishment rate of cattle manure is inversely proportional to the decomposition rate and that the base application rate in sandy soil must be higher than in red earth due to its higher decomposition rate.

Further investigations must be carried for crop response in order to gauge initial base application rates.
USE OF POULTRY LITTER FOR VEGETABLE PRODUCTION

S Sunassee
Agricultural Research and Extension Unit

ABSTRACT

Four field trials on carrot Daucus carota cv. chantenay 8” and cabbage Brassica oleracea var. capitata cv Rotan were carried out at two sites to investigate the potential of poultry litter as a replacement for cattle manure and to examine the effects of poultry litter in an acid and a slightly acidic soil. Cattle manure and poultry litter were applied at 0, 5, 10, 15 and 20 t ha⁻¹ on dry weight basis. It was found that manure did not have any significant effect on weight of cabbage in slightly acid soil of the Réduit CRS. However, the total plant weight and fresh weight of carrots grown in a slightly acid soil were significantly higher when manure was applied and poultry litter was as good as cattle manure. The type of manure did affect the soil pH significantly (P ≤ 0.05) for both crops. In slightly acidic soils application of cattle manure above 5 t ha⁻¹ raised soil pH to above pH 7 which may not be desirable. Poultry litter should be applied at 5 t ha⁻¹ for high yields, pH improvement and economic use of the manure. In acid soils an application rate of 15 t ha⁻¹ of poultry litter improved soil pH by about one unit coupled with best crop yields. However, it should be noted that the pH improvement is short lived and lasted for less than 30 days.

INTRODUCTION

Cattle manure has become increasingly scarce and expensive as a result of a persistent decline in local livestock activities. Foodcrop growers are therefore turning more and more to poultry litter as an alternative source of organic manure. Poultry litter consists of a mixture of poultry droppings and wood shavings or sawdust. It has been reported that besides organic matter, poultry litter is also a good source of nitrogen (Kirchmann H 1991, Mitchell C and Donald J 1995). Moreover, it is also reported that poultry litter has some liming value and that it may increase the soil pH slightly (Mitchell C and Donald J 1995). The purpose of this study was to investigate the potential of poultry litter as a replacement for cattle manure and to examine the effects of poultry litter in acid and slightly acidic soils.

MATERIALS AND METHODS

Field trials on carrot (Daucus carota cv. chanteney 8”) and cabbage (Brassica oleracea var. capitata cv Rotan) were conducted at the Réduit Crop Research Station (Réduit CRS) and Wooton Crop Research Station (Wooton CRS) between February 2000 and June 2000. The surface soil of the Réduit area varies in acidity from medium acid to slightly acid, the range in pH being from 5.8-6.6. (Parish and Feillafe, 1965). The soils of the Wooton CRS are strongly to slightly acid, pH varying from 5.0-6.3. A total of 4 trials were conducted at the two different sites to assess the effects of fresh cattle manure and poultry litter at the rate of 5, 10, 15, 20 t ha⁻¹ (on dry weight basis) on crop performance and soil chemical characteristics. No manure was applied to the control plot. Soil pH were recorded from composite samples taken from 15 cm soil depth before addition of animal manures, at addition of manures before planting, one month after sowing/ transplanting and at harvest. The total and available N, P, K and organic matter content of the soil were analysed before addition of animal manures and at harvest.

Total yield (head + outer leaves fresh weight) and head yield (fresh head weight) were parameters recorded for cabbage. Total plant yield (fresh weight of carrots with leaves) and carrot yield (fresh weight of carrots without leaves) were recorded.
RESULTS AND DISCUSSION

It was observed that the pH of fresh poultry litter (8.45) was higher than that of cattle manure (7.85). Application of fresh poultry litter may improve the pH of the acidic soils of the uplands, but may render the soils near the coastal areas alkaline. Chemical analysis also revealed that poultry litter has a higher content of available nitrogen and phosphorus content than cattle manure by 163% and 157% respectively. It has been reported that 30% of the nitrogen from poultry litter is in urea/ammonium form and is readily available similar to commercial mineral fertilisers (Kirchmann, H. 1991, Mitchell C and Donald J. 1995). Poultry litter can thus replace part of the mineral fertiliser nitrogen applied to foodcrop. The C/N ratio of poultry litter (7) is lower compared to cattle manure (20). The C/N ratio of poultry litter is too low for proper decomposition and would result in the loss of nitrogen through ammonia volatilisation (Kiyonori H.1990). He suggested that for proper decomposition the C/N ratio of poultry litter should be made to lie between 20:1 to 30:1 through incorporation of carbon rich plant materials.

Statistical analysis revealed no significant differences, at the 5 % level, between the individual treatments for total fresh weight and fresh head weight of cabbage at both Réduit CRS and Wooton CRS. At Réduit CRS the type of manure did not have any significant effect on cabbage total and head weights at the 5 % level. However, cabbage head weights obtained at manure application rate of 5 t ha⁻¹ were significantly higher than the other levels. At Wooton CRS significantly lowest total and head weights were obtained with cattle manure compared to the control and poultry litter treatments. The effect of levels of manure application was non significant at the 5 % level. At rates above 15 t ha⁻¹ cabbage head yields were higher by about 28 % when poultry litter was applied compared to cattle manure. Poultry litter is better than cattle manure for cabbage at Wooton CRS. Lack of positive response to increasing levels of poultry litter could be due to the fact that the low C/N ratio probably results in the loss of nitrogen through volatilisation and leaching. At Réduit CRS manure did not have any significant effect on cabbage yields. This could be due to the fact that the chemical fertiliser applied may have already provided the required nitrogen. Table 1 shows the results of the total plant weight (TW) of carrots and the carrot weight (CW) per square metre under the different treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Manure rate (tha⁻¹)</th>
<th>Réduit CRS</th>
<th></th>
<th>Wooton CRS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TW</td>
<td>CW</td>
<td>TW</td>
<td>CW</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>3.619</td>
<td>2.238</td>
<td>6.200</td>
<td>5.019</td>
<td></td>
</tr>
<tr>
<td>Cattle manure</td>
<td>5</td>
<td>4.700</td>
<td>3.050</td>
<td>4.795</td>
<td>4.163</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4.613</td>
<td>2.925</td>
<td>4.209</td>
<td>3.646</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4.781</td>
<td>2.900</td>
<td>7.281</td>
<td>5.994</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>3.806</td>
<td>2.337</td>
<td>6.764</td>
<td>5.919</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>5</td>
<td>4.312</td>
<td>2.800</td>
<td>6.835</td>
<td>5.198</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4.975</td>
<td>3.050</td>
<td>6.166</td>
<td>5.085</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4.338</td>
<td>2.675</td>
<td>8.488</td>
<td>6.924</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4.313</td>
<td>2.875</td>
<td>7.825</td>
<td>4.925</td>
</tr>
<tr>
<td>S.E ±</td>
<td>1.430</td>
<td>2.210</td>
<td>0.880</td>
<td>0.800</td>
<td></td>
</tr>
</tbody>
</table>

Higher yields were obtained at Wooton CRS due to favourable climatic conditions for carrots existing at Wooton CRS. At Réduit CRS the total plant and carrot weights were significantly higher when poultry litter and cattle manure were applied compared to control. The average total plant yield and average carrot yield were similar for both poultry litter and cattle manure. This indicates that poultry litter is not better than cattle manure but that it is a good alternative. Manure rates did not have any significant effect on carrot yields. Thus, an application rate of 5 t ha⁻¹ is appropriate for carrot at Reduit CRS. At Wooton CRS total plant weight of carrots and carrot weight were significantly affected by the treatments imposed. Application of poultry litter gave better yields than application of cattle manure and the control. The level of poultry litter application affected carrot yield significantly. In fact the highest total plant yield and carrot yield were obtained with poultry litter at 15 t ha⁻¹ (8.49 kg m⁻² and 6.93 kg m⁻² respectively). Lowest average total plant yield and average carrot yield were obtained with cattle manure (5.76 kg m⁻² and 4.93 kg m⁻² respectively). Similar to the trial with cabbage at
Use of poultry litter for vegetable production. Sunassee S

Wooton CRS, poultry litter is better than cattle manure. At Wooton CRS poultry litter is better than cattle manure for growing carrots and an application rate of 15 t ha\(^{-1}\) is appropriate. No significant differences (\(P \leq 0.05\)) in soil pH were found between treatments before application of manure and at harvest for both crops at both sites. The soil pH at application of manure and at 30 days after manure application were significantly different to the soil pH at the other times when pH were analysed. Significant differences in soil pH were noted between manures. When manure was applied to cabbage at Wooton CRS the soil pH changed to varying levels depending on treatments (Table 2). Cattle manure could not raise pH to the optimum pH range of 5.5-6.5 for cultivable soil. The most significant increase in soil pH were obtained at the time of poultry litter application at the rate of 15 and 20 t ha\(^{-1}\). Soil pH at those two levels were not significantly different (\(P < 0.05\)). Poultry litter at 15 and 20 t ha\(^{-1}\) did increase soil pH by 1.2 units to 5.93 and 6.12 respectively. However, the effect of the litter on soil pH was only short lived since 30 days after application no significant increase in soil pH was detected. This could be explained by the fact that the ammonium ions present in poultry droppings are readily mineralised within 2 weeks (Kirchmann H 1991) and thus the alkalinisation effect is only very short. Similar results were obtained with carrot at Wooton CRS except that application of poultry litter at 20 t ha\(^{-1}\) produced the greatest significant increase (+1.64) in soil pH. In fact pH rose from 5.17 to 6.81. Likewise the effect on soil pH was not maintained since 30 days after application of poultry litter no significant improvement in soil pH was observed. Application of poultry litter above 15 t ha\(^{-1}\) did not significantly increase cabbage and carrot weights. Thus, an application rate of 15 t ha\(^{-1}\) is best for cabbage and carrots at Wooton CRS is appropriate.

At Reduit CRS the effect of application of manure on soil pH was significantly different (\(P \leq 0.05\)) at the time of application of manure only. Thus the change in soil pH lasted for less than 30 days. The effect of poultry litter on soil pH for cabbage was significantly higher compared to the effects of cattle manure and the control. Application of cattle manure improved soil pH by 0.29 whereas application of poultry litter increased soil pH by 1.32 units. However, in view of the relatively higher soil pH prevailing at Reduit CRS application of poultry litter at and above 15 t ha\(^{-1}\) increase the soil to pH above 7.0. This is not desirable since nutrient availability may be limited through fixation and volatilisation. In fact no significant increase in cabbage and carrot yields were obtained at poultry litter application rates higher than 10 t ha\(^{-1}\). Figure 1 shows the effect of type of manure on soil pH change for carrots at Wooton CRS and Reduit CRS at the time of manure application. It can be seen that for improving soil pH poultry litter is better than cattle manure and that the changes in soil pH are higher in acidic soils. At Reduit CRS the highest significant rise in soil pH were obtained when poultry litter was applied at and above 15 t ha\(^{-1}\) to carrots.

At the same time it can be observed that yields of carrot were lower at 15 t ha\(^{-1}\) and 20 t ha\(^{-1}\) application rate compared to the lower application rate of 10 t ha\(^{-1}\) (Table 1). For soil pH improvement, poultry litter is better than cattle manure. In slightly acidic soils such as that of Reduit CRS poultry litter should be applied at 5 t ha\(^{-1}\) for high yields, soil pH improvement and economic use of the manure.

CONCLUSION

Due to its alkalinity application of fresh poultry litter may improve the pH of the acidic soils of the uplands, but may render the soils near the coastal areas alkaline which may be undesirable. Results of analysis revealed that poultry litter has a higher content of available nitrogen and phosphorus content than cattle manure by 163 % and 157 % respectively. The ability of poultry litter to replace part of the mineral fertiliser nitrogen applied to foodcrop needs to be investigated. At Réduit CRS manure did not have any significant effect on cabbage yields. This could be due to the fact that the chemical fertiliser applied may have already provided the required nitrogen. However, with carrots yields were significantly higher when manure was applied compared to control and that poultry litter was as good as cattle manure. In slightly acidic soils like the Réduit CRS poultry litter should be applied at 5 t ha\(^{-1}\) for high yields, pH improvement and economic use of the manure. Application of poultry litter above 15 t ha\(^{-1}\) raises soil pH to above 7.0 which may not be desirable for most foodcrops. Moreover, nitrates may leach and become a source of pollutant. Poultry litter was better than cattle manure for both carrot and cabbage production at Wooton CRS. Cattle manure cannot raise the soil pH of acid soils to the
Use of poultry litter for vegetable production. Sunassee S

**Figure 1** Effect of type of manure on soil pH change at Wooton CRS and Réduit CRS at the time of manure application

![Figure 1](image)

**Table 2** Effect of manure on soil pH before, at and 30 days after application and at harvest for cabbage at Wooton CRS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Manure Rate (tha)</th>
<th>Soil pH</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>At</td>
<td>30 days after</td>
<td>At harvest</td>
</tr>
<tr>
<td>Control</td>
<td>4.62</td>
<td>4.55</td>
<td>5.39</td>
<td>4.50</td>
</tr>
<tr>
<td>Cattle manure</td>
<td>5</td>
<td>4.92</td>
<td>5.39</td>
<td>4.92</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4.98</td>
<td>5.14</td>
<td>4.72</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4.77</td>
<td>5.12</td>
<td>4.69</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4.61</td>
<td>5.33</td>
<td>4.68</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>5</td>
<td>4.87</td>
<td>5.01</td>
<td>4.95</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4.64</td>
<td>5.39</td>
<td>4.94</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4.74</td>
<td>5.39</td>
<td>4.92</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4.93</td>
<td>5.39</td>
<td>4.95</td>
</tr>
</tbody>
</table>

S.E ± 0.11 0.08 0.06 0.09

Means followed by at least one common letter in their superscript are not significantly different (DM RT, 5% level).

The most significant increase in soil pH (averaging 1.2 units) were obtained at the time of poultry litter application at high levels of 15 and 20 t ha⁻¹. An application rate of 15 t ha⁻¹ of poultry litter is recommended for acid soils similar to that of the Wooton CRS. However, it should be noted that the increase in pH lasts for less than 30 days and that the effect of pH improvement through poultry litter application could be beneficial to short cycle crops mainly.

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Author and Subject Index

A case study of farmer participatory research: The optimum density of tomato ..................23
A simple procedure for staining the bones of the silver sea bream, *Rhabdosargus sarba* ..................................................253
A study of the prospects and potential of late production of onion in the region of la Marie ..................................................57
A three-phase approach (OPI) as a research methodology to conduct in-depth investigations on the agricultural activities of small-scale farmers ..................................................31
Abeeluck ......................................................91
Alternate substrates for anthurium production .... 45
Appave ........................................................1
Application d’un nouveau procédé de salaison à la valorisation de la venaison .......... 167
Applications of video image analysis in agriculture ...................................................... 9
Arlandoo ..............................................195
Assessment of the chloride status in the tobacco leaf and some potential sources for the high chloride level ............ 65
Atawoo ......................................................65
Autrey ..........................................................9
Baborun ......................................................73
Barbe .........................................................135
Basant Rai ..................................................219
Bheekhee ..................................................179, 189
Bhudoye ......................................................253
Blanfort ......................................................53
Boodoo ......................................................245, 249
Cadersa ......................................................65
Chemosystematics: A new source of evidence for the classification of the endemic flora of Mauritius ........................................ 73
Chineah ......................................................211, 219
Choomun ......................................................219
Chung Tze Cheong ........................................1
Collignan ....................................................167
Crop cycle study in pineapple: Preliminary results ......................................................53
Deumier .....................................................167
Developing a geographic information system (GIS) tool for extension purposes in Mauritius ..................................................1
Dobee .........................................................179
Duyck .........................................................105
Effect of lime on nutrient content of soils, yield and nutrient content of potato and infestation by leaf miners .................. 139
Elimination of sugarcane yellow leaf virus and sugarcane bacilliform virus by tissue culture ....................................................127
Etude comparée de la biologie du développement chez trois espèces de mouches des fruits (*Ceratitis* spp.) (Diptera : tephritidae), nuisibles aux cultures fruitières à la Réunion ...........................................105
Evaluation of the performance of deer weaners on three different feed supplements .......... 179
Fabre ..............................................................99
Fakhnath .....................................................81, 139
Fakim .........................................................179
Foreword ..................................................ix
Gaugnoo ......................................................135
Gestion raisonnée des pâturages dans les élevages de cervidés mauriciens .......... 189
Ghooorbin ......................................................91
Govinden ......................................................23
Gowrea ......................................................23
Grimaud ......................................................167, 173, 189
Iwamoto .....................................................237
Handling large populations of sugar cane genotypes at early stages of selection in Mauritius ..................................................115
Hanoomanjee ...............................................37, 57
Hassea .........................................................231, 237
Hiromi .........................................................253
Hurbungs .....................................................211
Increasing smallholder milk production through adoption of concentrate supplementation .......................................................249
Information technology in agricultural research and extension ................................... xv
Isolation and identification of infectious bursal disease virus in cell culture from clinical cases ..................................................195
Iwamoto ......................................................231, 237
Jamala ..........................................................1
James .......................................................... xv
Jaumally ......................................................195
Jayabalan .....................................................211, 219
Jugurnauth ......................................................37
Keynote address ................................................. xv
Khadun .........................................................231
Khittoo .........................................................73
Lai Fang .........................................................73
Lalljee ...........................................................81, 139
Le suivi de gestion raisonnée des prairies à la Réunion ..................................................173
Les vitamines du groupe B de quelques variétés de riz malgaches en provenance de Marovoay et de Tuléar: Mise au point de la méthode et détermination quantitative .................................. 157
Lousta Lalanee ..................................................257
Lutte intégrée contre les ravageurs des cultures maraîchères à la Réunion ...........................................99
Mangar ...........................................................9
Michon .........................................................173
Minister’s address ...........................................xi
Moothien Pillay ................................................219
Moutia ..........................................................9
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Agriculture: A myth or reality in the Mauritian context?</td>
<td>81</td>
</tr>
<tr>
<td>Overview of an experimental release method of the silver sea bream in the lagoon at Albion (Petite Rivière Bay)</td>
<td>231</td>
</tr>
<tr>
<td>Oxadiargyl: A new pre-emergence herbicide recommended in potato in Mauritius</td>
<td>135</td>
</tr>
<tr>
<td>Pilot plant investigation of the treatment of synthetic sugar factory wastewater using the upflow anaerobic sludge blanket (UASB) process</td>
<td>149</td>
</tr>
<tr>
<td>Potential of olfactory and visual baits for the control of Stomoxys nigra Macq. (Murcidæ: Diptera) in Mauritius</td>
<td>91</td>
</tr>
<tr>
<td>Production of major colocasia spp. in mauritius: Current status, constraints and opportunities</td>
<td>37</td>
</tr>
<tr>
<td>Seasonal distribution of potentially toxic benthic dinoflagellates in the lagoon of Trou aux Biches, Mauritius</td>
<td>211</td>
</tr>
<tr>
<td>Table of contents</td>
<td>vii</td>
</tr>
<tr>
<td>Welcoming address</td>
<td>x</td>
</tr>
</tbody>
</table>

**Rivet** 115  
**Rummun** 23  
**Ryckewaert** 99  
**Khadun** 237  
**Saddul** 245  
**Sakurdeep** 9  
**Sano** 237  
**Santchurn** 115  
**Saufally** 9, 127  
**Sauzier** 189  
**Srivastava** 195  
**Status of the marine environment of the Flic en Flac lagoon, Mauritius** 219  
**Sunassee** 259  
**Teeluck** 9  
**Terai** 219  
**Terashima** 219  
**The decompostion rate of cattle manure in the two main soil types of the Seychelles** 257  
**Thomas** 173, 189  
**Toolsee** 249  
**Use of poultry litter for vegetable production** 259  
**Vencatasamy** 57  
**Ver a soie et poisson** 203  
**Voahanginirina** 157  
**Welcoming address** x  
**Wong Sak Hoi** 149