PT337

Sustainable potato production in highland areas of Australia

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HAL

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PT337

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INDUSTRY SUMMARY

In 1990 growers in the Robertson potato growing district began to develop and adopt significant new approaches to soil conservation and land management. The adoption of these sustainable farm practices resulted in lost farming land of 15-20% due to earthworks.

In order to remain viable growers have been working with NSW Agriculture, Land and Water Conservation and a local consultant to implement strategies to improve environmental sustainability while increasing yields. This has been done through project PT337 - "Sustainable Potato Production in Highland Areas of Australia", by developing minimum tillage techniques with the assistance of Landcare and DLWC, nutrient, irrigation, and pest & disease monitoring programs, as well as sourcing research information from other districts throughout Australia.

Minimum Tillage
Minimum tillage has been compared with conventional tillage methods. Funding for equipment was met by the National Landcare Program Results show yield to be at least equal to conventional methods. Costs are decreased due to less fuel used, less wear and tear on tractors and implements, less growers' time spent in tractor driving, less soil structure damage.

Nutrient Monitoring
Soil testing before the season begins, followed by a program of plant testing during the season has illustrated to growers the need to re think fertiliser application rates. Nutrient testing has shown growers that differences in planting times can have major effects on nitrogen levels in the plant. Potassium has been highlighted as a nutrient to monitor during the season as a side dressing may be necessary.

Data collected over 3 consecutive seasons has created a very good picture of the district and is helping to develop appropriate fertiliser programs for individual paddocks as well as for different potato varieties.

Irrigation Monitoring
Tensiometers have become an integral part of the Robertson growers crop management program. Traditionally irrigation has been used to supplement rainfall. Tensiometers have demonstrated to growers how well drained the soils in the Robertson district are and how quickly crops can become water stressed. Crops irrigated according to tensiometer results gave consistently better yields (45t/ha) than those irrigated by guess work (30t/ha).

Pest and Disease
The growers have worked very closely with Robert Spooner-Hart and the project PT 336 to Implement IPM in Northern Australia. Growers are now able to monitor for and recognise insects present. Growers are aware of biological control programs and wish to implement one for the control of potato tuber moth. As a result of exposure to the project and their increased awareness of insect pests and their control, growers decided to undertake the National Farm Chemical Users Course. All participants gained certification.

Investigatory Trials
Nutrition trials have been the main focus of the Sustainable project due to the high amounts of fertiliser applied and the sensitivity of waterways in the district to increased nutrient levels. The project looked at high, low and normal rates of phosphorus and higher application rates for potassium at and before planting.. From this work it was concluded that applications of phosphorus can be lowered depending on soil test results. High applications of potassium at or before planting do not improve yield or plant uptake over the season and side dressings may be more appropriate.

Networking
Monthly meetings have been organised where guest speakers are invited. Topics covered include industry issues and research. A newsletter has been prepared outlining the work being carried out by the growers in relation to the project. This is sent to all participating growers, grower groups throughout NSW and support persons throughout Australia. District visits have also been an integral part of the project. These have led to a better understanding of what is happening elsewhere and to let other districts know of the work and results in Robertson.

Handbook of Best practice
To ensure the work of this project is not lost, all activities and outcomes have been documented in a handbook of best practice. This handbook will also provide factsheets on areas of nutrition, pest, disease and irrigation.

TECHNICAL SUMMARY

In 1990 growers in the Robertson potato growing district began to develop and adopt significant new approaches to soil conservation and land management. The adoption of these sustainable farm practices resulted in lost farming land of 15-20% due to earthworks.

In order to remain viable growers have been working with NSW Agriculture, Land and Water Conservation and a local consultant to implement strategies to improve environmental sustainability while increasing yields. This has been done through project PT337 - "Sustainable Potato Production in Highland Areas of Australia", by developing minimum tillage techniques, nutrient, irrigation, and pest & disease monitoring programs, as well as sourcing research information from other districts throughout Australia.

What have we achieved.

Yield increases of 18% have been recorded over the 3 years of the project. Greater sustainability has been achieved through more appropriate use of chemicals and fertilisers.

Growers are aware of the latest technologies, products, and support specialists. In order to implement the technology successfully into their crop management program.

Very importantly this project clearly demonstrates the benefits of a group co-operating and working together. The Association has been able to negotiate a special rate for soil and plant testing. Research institutes identify the group as proactive and actively seek out the group for joint project work.

Strong links have been developed between the growers, local government and state agencies, demonstrating to the community that potato farmers are responsible primary producers.

A survey of growers was conducted at the conclusion of the project to determine the rate of adoption of new technologies, Table 1 summarises these results.

Table 1: Adoption rate of New Technology.

	% adoption
Minimum Tillage	54.5%
Irrigation management	64%
Soil testing	73%
Plant testing	36%
IPM	64%

The Future

The work undertaken by the Robertson District Potato Advancement & Landcare Association (RDPA&LA) has identified major inefficiencies in irrigation practices, and the need to develop management strategies for phosphorus in krasnozem soils. There is also a desire to implement biological control measures for the management of the potato tuber moth, a major pest of potatoes.

To address these issues the RDPA&LA would like to implement a project with the following aims:

- Develop phosphorus management strategies for krasnozem soils in the Robertson district.
- To improve water use efficiency and minimise soil and nutrient run off.
- Establish biological control techniques in the Robertson district for the management of potato moth in order to minimise pesticide applications.
- Establish a strong forum through which growers are able to source information on technologies which will improve their economic viability and achieve land use sustainability.
- Expand the project work to include other districts in order to increase the potential for idea development.

PROJECT FUNDING

Project PT337 - "Sustainable Potato Production in Highland Areas of Australia" has been funded through the:

- Horticultural Research and Development Corporation
- Robertson District Potato Advancement and Landcare Association.
- Australian Potato Industry Council.
- Sydney Water
- Wingecarribee Shire Council.

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INTRODUCTION

The project "Sustainable Potato Production in Highland Areas of Australia" commenced in November 1993 and will be completed in October 1996. This project has been funded by the Robertson District Potato Advancement and Landcare Association, the Horticultural Research and Development Corporation, the Potato Levy, Wingecarribee Shire Council and Sydney Water Authority. The project has been closely supported by NSW Agriculture and Land and Water Resources.

The implementation of this project occurred because traditional farming practices in highland potato growing areas of NSW are being increasingly challenged by environmental groups, catchment authorities, Landcare groups, growers and industry leaders. They see ample evidence of soil degradation, particularly soil erosion and falling viability.

In some potato growing districts new settlers are organising into pressure groups that focus on environmental problems, especially those due to conventional farming practices. There is a need to develop new sustainable potato growing strategies and in some areas such as Robertson growers have already begun adopting significant new approaches to soil conservation and land management. These breakthrough successes were in danger of stalling and gains lost, because of resource staff transfers and a concentrated lack of direction in continuing with research and extension. It has been demonstrated that sustainable environmentally acceptable farming practices result in lost farming lands of 15-20% due to earthworks. Therefore farmers must increase production from reduced field area to remain viable.

There existed a need to demonstrate to growers techniques that increase production levels and returns and guaranteed the future of the industry. The adoption of yield boosting technologies associated with crop monitoring is very low. The benefits of comparative analysis had never been demonstrated to growers and is another avenue for growers to lift productivity and profit levels.

Highland farms are always at risk due to the undulating nature of topography heavy reliance on clean cultivation techniques and the menace of high rainfall and heavy storms.

These potato growing areas are vital industry contributors, producing potatoes for ware, processing and seed. The growers are keenly aware of the need to adopt more sustainable practices. However a lack of verified information from research and low levels of technical support to the industries that have traditionally been scattered and difficult to service by advisory staff has meant low levels of adoption of improved farming practices.

The aims of this project were as follows:

- To further develop by September 1996 viable, sustainable and environmentally safe potato growing strategies for highland areas of NSW that are nationally acceptable.
- By September 1996 achieve a 40% increase in the adoption of recently developed and evolving cultural practices in NSW highland potato farms.
- By September 1996 achieve a viable, sustainable and environmentally acceptable 20% increase in potato returns at Robertson NSW to underpin the second objective.

To achieve these aims the Robertson District Potato Advancement and Landcare Association (RDPA&LA) undertook a comprehensive monitoring program as well as small investigation trials.

The monitoring program included the following crop management areas, land management, nutrition, irrigation, pest and disease.

This report details the work carried out by the RDPA&LA and the results and recommendations from this work.

PROCEDURE

Project Development:

The RDPA&LA worked closely with NSW Agriculture and the Department of Land and Water Conservation to develop project PT337 - Sustainable Potato Production in Highland Areas of Australia". Close liaison was also had with HRDC in the development of this project.

Appointment of project coordinator:

The first objective of the project was to appoint a project coordinator to ensure the smooth running of the work, timely results and a contact point for growers, researchers, and all industry persons.

Development of project structure & procedure:

A general survey was made of all participating growers to determine what they were wanting to gain from the project and in what areas they wanted trial or monitoring work conducted.

A meeting was then held with the Grower Committee to develop a plan and structure to address issues highlighted by the survey results.

Areas identified in this survey were fairly general and covered nutrition management, irrigation management, pest and disease management, and land management.

A program of demonstration trials was developed to address specific nutrition aspects, as well as a comprehensive monitoring program of soil testing and plant nutrient testing. Soil moisture monitoring began with the use of tensiometers. To help with the interpretation of results Mike Robbins an irrigation officer from NSW Agriculture was consulted. Close links with the project PT336 - Development of IPM in Northern Australia were formed to address issues of pest management. The Department of Land and Water Conservation in NSW collaborated with the project in the development of minimum tillage techniques.

To encourage grower interaction a program of discussion nights was formulated. These nights took place once a month and were held at the local pub.

A newsletter was published and sent to all participating growers, grower groups, and industry personnel to inform the industry of work being undertaken.

Publication of Grower Handbook:

To ensure all the work undertaken was documented and distributed to industry a handbook was published detailing the work.

End of project grower survey:

To gain an indication of how successful the project had been a short grower survey was conducted at the conclusion of the project.

Project Outcomes - Monitoring Program and Grower Survey

by
Sandra M Lanz
Project Co-ordinator

Contents:

INTRODUCTION:

The Robertson District Potato Advancement and Landcare Association began implementing land management techniques in the early 1990's to manage soil erosion and maintain their sustainability as potato growers in the Sydney and South Coast water catchments.

This work led to a loss of 15-20% of cropping land. To maintain growers economic viability an increase of 20% in farm income was needed from the same production area. This need led to the development of project PT337 - Sustainable Potato Production in Highland Areas of Australia.

The project structure and activities was developed by the growers in collaboration with a project coordinator who implemented these activities.

Areas of investigation included; irrigation, nutrition, pest and disease management, and minimum tillage. Strong links with NSW Agriculture, Department of Land and Water Conservation, and Landcare were developed to address irrigation and minimum tillage issues. Much of the pest and disease management was addressed through strong collaboration with project PT336 - IPM in Northern Australia. Other activities of the project included field days, discussion nights, seminars, demonstration trials, district visits, and a newsletter.

The actual outcomes / objectives of the project were:

- To further develop by September 1996 a viable, sustainable and environmentally acceptable set of cultural practices for potato production in NSW highland areas that are relevant and acceptable nationally.
- By September 1996 achieve a 40% increase in the adoption of recently developed and evolving cultural practices in NSW highland potato farms.
- By September 1996 achieve viable, sustainable and environmentally acceptable 20% increase in potato returns at Robertson NSW to underpin the second objective.

MEASUREMENT OF OUTCOMES:

Monitoring Program:

To measure changes in crop yield over the 3 years of the project a monitoring program was developed. This monitoring program identified 2 paddocks on each participating growers property. Growers were encouraged to take a soil test pre season, plant tissue tests during the season, keep records of pesticide applications and irrigation. At the end of the season an estimation of yield was undertaken by digging 2 meters in 3 areas of the paddock, weighing all tubers dug, then grading tubers and determining the yield of No1 grade, smalls, large, and rejects (diseased, damaged tubers).

Grower Survey:

A grower survey was conducted at the conclusion of the project to gain an indication of growers perception of the projects success or failure.

This survey was developed by the Project Coordinator, then forwarded to the Association secretary in order to gain input from the Association. The secretary then posted it out to all participating growers. Follow up phone calls were made by the secretary to encourage growers to fill in and return the survey and to answer any queries growers may have in regard to the survey.

RESULTS:

Monitoring Program:

Table 1 summarises the change in average yield recorded as part of the monitoring program developed for project PT337 Sustainable potato production in highland areas of Australia. An 18% increase in average yield was obtained over the life of the project.

Table 1: Change in average yield over the life of the project.

	Average Yield	% increase from year 1
1993/94	37.5 t/ha	
1994/95	42.9 t/ha	14%
1995/96	44.2 t/ha	18%

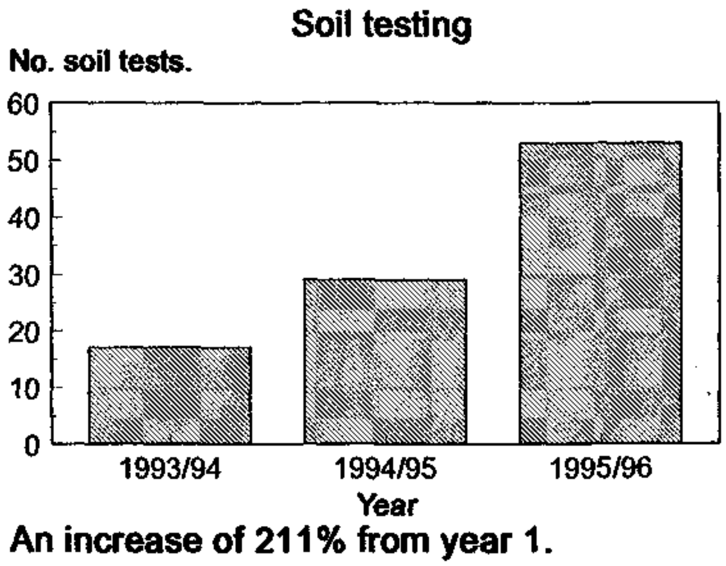


Figure 1: Number of Soil tests recorded for each year of the project.

As part of the monitoring program records of the number of soil tests undertaken by growers were kept by the project coordinator. Figure 1 illustrates that between year 1 and year 3 of the project an increase of 211% was experienced.

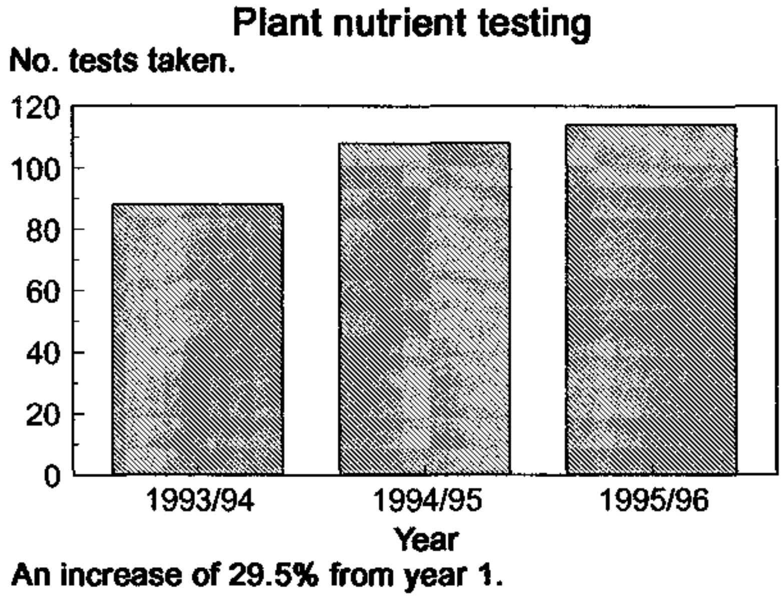


Figure 2: Number of Plant nutrient tests recorded for each year of the project.

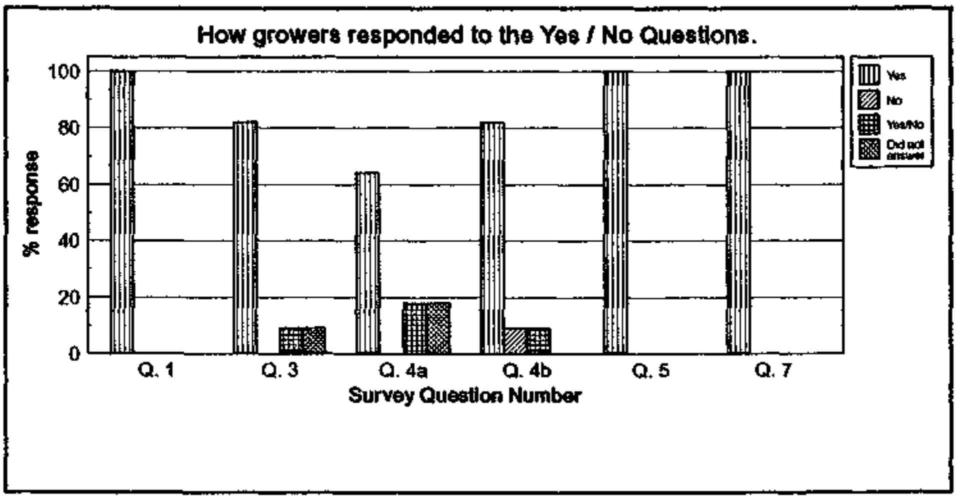
As part of the monitoring program records of the number of plant nutrient tests undertaken by growers were kept by the project coordinator. Figure 2 illustrates that between year 1 and year 3 of the project an increase of 29.5% was experienced.

It was also noted by the project coordinator that in year 3 of the project 85% of participating growers were using tensiometers to monitor soil moisture.

Grower Survey:

A total of 14 surveys were sent out and 11 responses were received, which is a 78.6% response rate.

A number of Yes / No questions were asked and the results are illustrated in Figure 3.



Q. 1 - Have you adopted new crop management strategies / technologies since the sart of the project?

Q. 3 - If YES was this as a result of the project?

Q. 4 - By adopting new crop management strategies / technologies have you seen an:
a) Increase in average yield.
b) Decrease in input costs.

Q. 5 - Were you happy with the "Handbook of Best Practice"?

Q. 7 - Did you find the project beneficial?

Figure 3: Growers responses to the Yes / No Question in the survey.

Question 2 of the survey asked growers to list the areas in which they had adopted new crop management strategies or technologies since the project began. The project had 5 areas where specific work was undertaken. These areas included: minimum tillage, irrigation, soil testing, plant testing, and IPM. Responses to question 2 were divided into these main areas to obtain an indication of a change in grower practices within the specific areas of work. Table 2 summarises the results.

Table 2: Adoption rate of new technology in project PT337.

	% adoption
Minimum Tillage	54.5%
Irrigation management	64%
Soil testing	73%
Plant testing	36%
IPM	64%

The important thing to note is growers were not prompted in their responses to this question. Other responses were also listed by growers and they often stated these changes came about due to discussions with guest speakers, and other growers.

The survey asked growers in what areas they found the project beneficial or not beneficial, following is a list of the responses received.

Benefits:

- Control over erosion.
- Improved irrigation.
- Efficient use of chemicals.
- Monthly speaker.
- Monitoring of insect infiltration.
- Coordination of project.
- Technology transfer.
- Acceleration in development of own ideas by interaction with other growers and guest speakers.
- Access to latest technology.
- Transfer of information.
- Fertiliser trials.
- Communication with other growers.
- Interpretation of results.
- Exchange of ideas.
- Interaction with potato groups in other districts.
- Interaction with Sydney Water, NSW Ag., Dept Land and Water Conservation, and Shire Council.

Areas found not to be beneficial:

- Some growers lack of commitment to the project.
- Creation of more questions rather than giving answers.

Growers were also asked to make any other comments they wished. Following is a summary of these comments.

- The project demonstrates the need for small growing areas to work in project groups.
- More grower participation and interest would be beneficial.
- No consistent communication between consultant and grower eg when taking samples so other matters could be discussed.
- Would like to see project continue and possibly expanded to include all farmers in the area.
- Need for recognition and assistance to young farmers throughout Australia. This project is one step in many for the recognition of young farmers.
- Overall the project brought growers together to solve any problem and developed a better understanding between growers, Soil conservation, Water Board, Council and Government agencies.

CONCLUSION:

The monitoring program and the grower survey demonstrate that the adoption of recently developed and evolving cultural practices has occurred. In most cases the adoption rate has been higher than the original aim of 40%.

An increase in average yield of 18% was recorded through the monitoring program. In the grower survey over 80% of growers indicated they had experienced a decline in input costs related to crop production. These results satisfy the original objective of increasing potato returns by 20%.

Secondary benefits gained through the activities of the project include the creation of positive links between farmers in the district, the Shire Council, Sydney Water, and various Government Agencies. This has helped breakdown the barrier of the "them and us" mentality.

The results from the grower survey and monitoring program demonstrate that project PT337 has achieved the objectives / outcomes initially set.

The achievements of PT337 have been noted by other potato farming districts in NSW and Australia. Two of these districts (Dorrigo and Guyra) wish to collaborate with the Robertson district in a new project scheduled to begin July 1997, subject to funding approval.

APPENDICES

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21 November 1996

Grower Survey.
PT337 - "Sustainable Potato Production in Highland Areas of Australia."

1) Have you adopted new crop management strategies / technologies since the start of the project?

YES / NO (please circle your answer)

2) If YES what are they?

____
____
____
____
____

3) If YES was this as a result of the project?

YES / NO (please circle your answer)

4) By adopting new crop management strategies / technologies have you seen an:

a) Increase in average yield. **YES / NO**

b) Decrease in input costs. **YES / NO**

5) Were you happy with the "Handbook of Best Practice."?

YES / NO (please circle your answer)

6) If you answered NO to 5) please explain why.

____
____
____
____
____

7) Did you find the project beneficial?

YES / NO (please circle your answer)

8) Please explain what areas you found / did not find beneficial.

____
____
____
____
____

9) Please make any further comments in the space below.

____
____
____
____
____

Responses obtained from Grower Survey for PT337 - Sustainable Potato Production in Highland Areas of Australia.

Grower No. / Question No.	1	2	3	4	5
1) Have you adopted new crop management strategies / technologies since the start of the project?	Y	Y	Y	Y	Y
2) If yes what are they.	Use of min till method. More efficient use of water. Soil testing so as to obtain max ylds from specific fertiliser sources. Leaf analysis testing for efficient N application during crop growth.	In Irrigation - utilising less water but the periods are more frequent Monitoring insecticide usage. Usage of min till practices	Use of tensiometers, soil testing, and insect monitoring.	An acceleration in developing ideas that I was formulating, this was achieved by talking to other growers, listening to speakers, and more actively following through technical advice eg fertiliser formulation (blends), crop planting, spray techniques.	soil conservation works - contour banks/silt traps. Irrigation management - reduced application. Pest management - reduced application / cost savings
3) If yes was this a result of the project?	Y	Y	Y	Y/N	Y
4) By adopting new strategies have you seen an: a) increase in ave yld	Y	Y	Y	Y/N	Y
b) decrease in input costs	Y	N	Y	Y/N	Y
5) Were you happy with the Handbook?	Y	Y	Y	Y	Y
6) If you answered no please explain why.					
7) Did you find the project beneficial?	Y	Y	Y	Y	Y

8) Please explain what areas you found / did not find beneficial.	We have much more control over soil erosion through min till, levy banks, contour drains, a much improved irrigation method, due mainly to the use of tensiometers, and more efficient use of expensive chemicals.	Beneficial: monthly speaker was informative, being able to monitor insect infiltration, coordination by project development officer of trials & information. Non Beneficial: some growers lack of commitment to project.	Technology transfer.	Answered in part by Q2 but also by going back and looking at practices that I have used & let go to some degree. a) to maximise the use of organic matter, b) soil amendments, c) crop hygiene - hearing of trouble caused to other growers & districts.	This project has been a very useful tool in accessing the latest technology, introduced a soil testing regime, We've learnt a considerable amount about pest identification (beneficials / pests). We use much less chemical than before.
9) Please make any further comments in the space below.				I feel that the smaller growing districts have to remain in project groups like we have had so we can keep up with technological developments.	More grower participation and interest would be beneficial.

Grower No. Question No.	6	7	8 & 9	10	11
1) Have you adopted new crop management strategies / technologies since the start of the project?	Y	Y	Y	Y	Y
2) If yes what are they.	Increased soil and plant tissue testing. improved irrigation. better pest & disease management.	soil testing - IPM - testing different blends of fertiliser & top dressing with N & K	Greater use of minimum till. Use of tensiometers. Soil analysis. Petiole sampling.	Reduced tillage techniques. monitoring of soil moisture levels. Soil testing to indicate deficiencies.. Increased interest in pest control using biological methods.	Semi min till, less cultivation overall, benefit of contour drains to prevent soil erosion, less chemical on crop, fertiliser requirements.
3) If yes was this a result of the project?		Y	Y	Y	Y
4) By adopting new strategies have you seen an: a) increase in ave yld	Y	Y		Y	Y/N
b) decrease in input costs	Y	Y	Y	Y	Y

5) Were you happy with the Handbook?	Y	Y	Y	Y	Y
6) If you answered no please explain why.					
7) Did you find the project beneficial?	Y	Y	Y	Y	Y
8) Please explain what areas you found / did not find beneficial.	Irrigation, pest & disease control were beneficial. Fertiliser work made more questions than were answered.	Beneficial: Transfer of information, fertiliser trials, communication with other growers, IPM, irrigation management, soil test and leaf analysis interpretation.	Better communication btw growers, exchange of ideas and receiving of technology through information nights. Particularly exchange of basic knowledge eg sources of seed, fertiliser and performance of machines etc. that would not have come about but for the project.	One benefit of the project is that it allowed for interaction of potato groups in the Robertson district with other districts, Sydney Water, NSW Ag, Land and Water Conservation, the Shire Council and other groups.	
9) Please make any further comments in the space below.		No consistent communication between consultant and grower eg when taking samples, no notification so other matters could be discussed.	We would like to see the project or projects continue in an expanded form to include all farmers in the area. There being a huge field of research that as yet has only been touched on the surface. Such as fertiliser usage, water usage, stocking capabilities, and the effect of pH on production etc.	One problem faced by potato growers of Australia, and many other agricultural industries is that not enough recognition and assistance is being given to young farmers. As the average age of farmers is around 59 and increasing this poses a problem to the future in Agriculture. The project just completed by Robertson potato growers is one step in many for the recognition of young farmers.	Overall project brought growers together to solve any problem, and better understanding between growers, Soil conservation, Water Board, Council & Govt departments.

Strategies for Sustainable Land Management

by
Guy van Owen
Department of Land and Water Conservation, NSW

Contents:

INTRODUCTION

The Robertson district, located in the Southern Highlands of NSW, is a significant potato growing area close to the Sydney market. The area accounts for some $2M dollars worth of high quality potatoes annually.

The basalt soils around Robertson are ideal for growing potatoes. They are well structured, free draining and have a low inherent soil erodibility. However, whilst thesusceptibility to erosion of the soil is low, actual erosion rates are high and unsustainable. Off site impacts are also significant due to high levels of sediment and nutrients entering local creeks. This is due to a combination of high rainfall erosivity (in the top 5% of the State), intensive tillage practices coinciding with peak storm periods, long (200m) and steep slopes (averaging 5-15% and up to 30%), and inadequate controls of stormwater runoff.

The industry has come under considerable pressure in recent years to address the soil loss problem due in part to its location in the water supply catchments of Sydney/Wollongong. High sediment loads entering local streams in the Robertson area and feeding Nepean and Tallowa dams were largely attributed to potato growing. Increasing scrutiny of the industry by local environmental groups and government authorities led local growers in 1991 to form the Robertson District Potato Advancement & Landcare Association. The group approached the then Soil Conservation Service of NSW (now Department of Land & Water Conservation), the Sydney Water Board (now Sydney Water) and NSW Agriculture to help them tackle the land degradation issue.

THE PROBLEM

The high rate of erosion and offsite impacts associated with growing potatoes around Robertson had to be addressed. Following a typical Robertson downpour, dams and local creeks draining cultivated paddocks invariably turn red. There have been instances in the past where local roads were made impassable and table drains choked with silt as a result of severe wash from paddocks (Photo 1). Clearly, such losses are unsustainable in the long term. Furthermore, the valuable topsoil that is lost from such events contain the majority of organic matter and soil nutrients (nitrogen, phosphorus, calcium, magnesium, potassium) essential for producing a crop. This is a direct economic cost to the landholder as well as causing water quality problems for water users downstream.

From soil test results collected from local farms over the last three years, 100 tonnes of topsoil lost from a hectare of worked up ground equates to:

Total Phosphorus	90 kg/ha
Total Nitrogen	400 kg/ha
Calcium	145 kg/ha
Magnesium	18 kg/ha
Potassium	22 kg/ha

The cost of replacing these nutrients totals around $920/ha at 1996 prices. In addition, some 6 t/ha of organic carbon (equivalent to10 t/ha of organic matter) would also be lost

Robertson is not unique in having to deal with this problem. Other potato growing areas such as Dorrigo, the Atherton Tablelands, Northern Tasmania, Gippsland and the Adelaide Hills face a very similar situation. All these potato growing areas have to deal with the same problems. Growing potatoes is an intensive land use practice and requires a considerable degree of soil disturbance. The soil is left bare for lengthy periods. The land used for potato production is usually steep. In most instances, growers have to contend with high rainfall intensity storms occurring during the growing season.

Rainfall Intensity:

The rainfall erosivity measure for the Robertson area is in the top 5% of the State. Rainfall erosivity is around 7,000, with 8,000 being the maximum for NSW (rainfall erosivity is a measure of the ability of rainfall to cause erosion). The more intense a rainfall event is, the higher its potential to erode soil. In general, rainfall erosivity is greatest in the warmest months (Dec, Jan, Feb). This is a real problem for growers because this period coincides with harvesting, when soil is bare and exposed to the elements. The result can be severe erosion and land degradation.

Topography:

Moderate to steeply sloping terrain used for growing potatoes is required to promote good drainage. Land used for growing potatoes varies in slope from 5 - 30% whilst slope length can be in excess of 200 metres. Erosion risk increases as slope gradients and slope length increase. In general, the preferred slope for cropping is 5-10%. Slopes steeper than 20% have an extreme erosion hazard rating and should not be cropped. Furthermore, the longer the slope, the greater the erosion hazard.

Intensive cultivation:

The basalt derived soils widely used for growing potatoes are well structured and have amongst the highest organic matter content of any Australian soil (5 to 6 times that of a typical wheat growing soil). However, traditional ground preparation can involve up to 8 operations with chisel ploughs, disk ploughs and rotary hoes. Weed control between the rows is often done by scuffling with tyned implements causing additional soil disturbance. Harvest operations with mechanical harvesters and diggers further damage the soil structure. A combination of such aggressive operations reduces organic matter content and pulverises soil structure. This reduces water infiltration and increases runoff leading to high rates of erosion.

SOLUTIONS

Since 1990, strategies to reduce the risk and severity of erosion and introduce more sustainable land use practices have been developed by Robertson growers in association with officers from the Department of Land and Water Conservation and NSW Agriculture. The principles developed are applicable to the industry nationwide and are equally relevant to intensive agriculture anywhere.

A - The Role of Earthworks (or Controlling Stormwater)

Results in the Robertson area have demonstrated beyond all doubt that a system of contourbanks, waterways and sediment traps can reduce the rate of erosion to minimal levels. Whilst these structures are expensive to build, they are permanent and their cost is generally a one off outlay. Further, costs can be offset by the subsidies provided by Sydney Water and DLWC and are eligible for tax concessions.

In broad acre cropping such as wheat, graded banks are spaced at distances in the paddock that will prevent soil erosion occurring under average conditions. These bank spacings are determined by a combination of slope gradient, soil type and condition, rainfall intensity for the area and cultivation practices adopted by the landholder. Following this formula, banks are spaced 100 to 140 metres apart on average.

To apply the same formula to potato paddocks around Robertson would mean bank spacings of 40 metres. This makes the concept impractical requiring a compromise solution. Instead, banks are spaced approximately 100 metres apart and provide a dual purpose; firstly they reduce slope length thereby reducing the severity of erosion when it occurs; secondly they act as sediment traps (Photo 2). It is therefore accepted that erosion will occur albeit at a reduced level. However, any sediment resulting from erosion is trapped on site and prevented from leaving the property. To further ensure the latter, sediment traps are included in the design of a paddock layout. These are located at strategic points in the paddock (usually on waste ground such as rocky outcrops or gullies and in the bottom corner of the paddock). To further control water flow within the crop and between the banks, graded furrows or drains are installed using a disc of moleboard plow. Special containment devices such as silt-stop fences or hay bales placed across flowlines can also be used.

An earthworks demonstration site was set up by the Soil Conservation Service (now the Department of Land and Water Conservation) on a property at East Kangaloon (near Robertson) in 1991. These earthworks proved their worth in June, 1991 when the paddock was subjected to over 600mm of rain over 4 days. At the time this paddock was completely exposed to the elements, having only recently been sown to oats which had not yet germinated. A subsequent survey carried out by the SCS revealed some 54 tonnes per hectare of soil had been mobilised by the storm and all but about 4% had been trapped by the earthworks (in the channels, waterway and sediment trap). Without the earthworks, predictive losses using computer modelling were between two and three times this tonnage (ie up to 150 tonnes per hectare). Worse, most of this sediment would have escaped off site with little to stop it entering the Nepean River less than one kilometre away.

The problem with graded banks on steep land is that they can take up an excessive amount of room in the paddock, the problem becoming worse the steeper the slope. This makes them less attractive in a region where cultivatable land is at a premium and very expensive. Such areas can still be treated however, by locating a diversion bank above the crop to divert any runon water and locating a second bank at the foot of the slope to collect sediment and divert it to a sediment trap. Banks can double as access tracks for farm vehicles, harvesters etc. (Photo 3) and are readily sown to oats (Photo 4) or permanent pasture. Often, a break of slope in the paddock will allow a bank to be constructed inside the crop. This should always be encouraged as the aim must always be to break the length of slope to manageable lengths so that runoff is always controlled. Runoff between the banks can also be controlled using grade furrows or drains.

Consideration should be given to leaving a narrow strip (5 metres wide) within the paddock to act as a waterway. All banks and drains should discharge to a grassed disposal area such as a waterway or stable natural watercourse leading to a sediment trap or farm dam. Waterways can double as irrigator runs. Figure 1 illustrates a typical layout of diversion and graded banks, waterways and sediment traps in a potato paddock in the Robertson area.

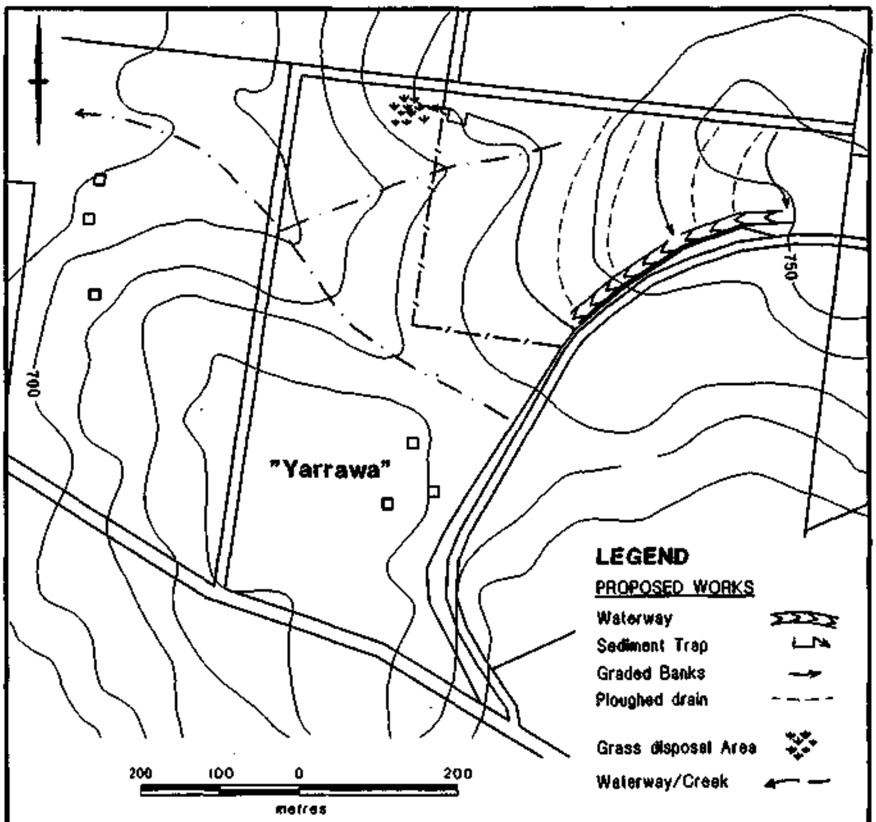


FIG 1 : TYPICAL LAYOUT OF EROSION CONTROL EARTHWORKS FOR POTATO PADDOCK, ROBERTSON

Photo 1 : High rates of erosion (100 to 150 t/ha) can occur on sloping potato paddocks following a typical Robertson storm.

Photo 2 : Diversion banks and sediment traps are very effective at preventing soil from escaping the property. The trapped sediment is then returned to the paddock when conditions allow.

Photo 3 : Well grassed diversion banks can provide convenient access for farm vehicles, harvesters etc.,

Photo 4 : and are a ready source of feed for cattle.

B - Minimum Tillage

Excessive cultivation is one of the main causes of serious soil erosion. Excessive cultivation destroys soil structure and reduces its organic matter content. This in turn reduces infiltration and increases surface runoff, greatly increasing the severity of erosion when it occurs. Studies in the Dorrigo area have shown that soil losses from pasture are minimal (100 kilograms per hectare per annum), whereas that from a regularly cultivated paddock can easily approach 150 tonnes per hectare per annum.

Whilst the red basalt soils around Roberston (Krasnozems) are renowned for their structural stability, largely a function of high iron and organic matter content. They are nevertheless badly affected by over cultivation. Soil aggregates smaller than 0.5mm are largely unaffected by cultivation as they are primarily formed and held together by the iron and aluminium. However, aggregates larger than 0.5mm are closely correlated with organic matter content. In other words, the larger crumbs collapse when the level of organic matter in the soil is reduced through cultivation.

For many years it was widely believed that a good potato crop could not be grown without first working the soil sufficiently to produce a fine tilth seed bed. This could involve up to 6 or more cultivations of a paddock prior to planting and often involved the use of very aggressive cultivators such as rotary hoes. Table 1 describes a range of conventional tillage (CT) practices used around Robertson compared to what would be considered minimum tillage (MT).

TABLE 2: TILLAGE PRACTICES, THEN AND NOW.

Case	Conventional - Past	Minimum Tillage
1	Offset disc (2) Disc or Mouldboard (1) Offset disc (1) Offset disc (1) Diamond harrow (1)	Spray Power Harrow (1) Press Wheels (1)
2	Rotary hoe (2) Chisel plough (1) Chisel & Harrow (1) Rotary Hoe (1)	Spray Power Harrow (1)
3	Chisel & Harrow (4) Agroplow & Harrow (2)	

To determine if potatoes could be grown successfully using only minimal ground preparation prior to sowing, two local growers agreed to trial a minimum tillage program on a portion of their properties, one at East Kangaloon and the other at Wildes Meadow. The trial involved the use of a modified Agroplow (a power harrow) developed in conjunction with one of the growers.

The power harrow, developed with the help of an NLP grant, had tynes fitted with a set of widesweeps designed to lift and fracture the subsoil. A gearbox driving two vertical roter blades and powered by the tractor was bolted to the frame (Photo 5).

Photo 5 : The modified Agroplow developed for the minimum tillage trials carried out on a number of properties in the Robertson area over the period 1992 to 1996.

Photo 6 : One pass into sprayed off paddock is sufficient to prepare a seedbed for planting. Another advantage is that only rows into which potatoes are sown are disturbed by rotary tynes, thereby keeping the area and degree of ground disturbance to minimum.

These blades worked up the ground behind the tynes in a circular manner, cultivating the ground sufficiently in one pass without inverting or "turning over" the soil. The speed of rotation of the tynes could be altered according to soil conditions prevailing at the time of ploughing.

Trials have been carried out over the last three years. Prior to this,an initial pilot trial was conducted on the East Kangaloon property in 1992/93. On each property, the power harrow was used to prepare a seed bed on a measured plot of ground (half to one hectare in size). An adjacent plot of the same size and having the same characteristics (soil type, aspect, slope, tillage history etc.) was prepared using conventional tillage techniques. The number of passes varied from season to season according to conditions pertaining at the time. However, the number of passes on the MT plot never exceeded two workings with the power harrow.

Gross Margins

Apart from establishing that potatoes could be grown successfully without the need to pulverise the soil, it was also considered that, by restricting the number of cultivations to one or two, the cost of production could be reduced and the enterprise become more profitable.

Growers conducting the trials were given record sheets and asked to keep accurate records of all work carried out on each plot from the first step in preparing the ground through to harvesting, bagging and storage in the shed. All costs associated with growing the crop, including the cost of seed potatoes, fertilisers, sprays, labour, bags, irrigation, machinery costs and fuel, as well as a component for wear and tear based on an hourly rate for usage. Gross margins for the plots were calculated at the end of each season and converted to per hectare figures.

Soil Structure Investigations

The trial also investigated the impact of cultivation on soil structure. At the commencement of each growing season and prior to cultivation, five surface cores (0-15cm) were collected randomly from each plot and analysed. To determine the long-term impacts of cultivation, soils representative of undisturbed areas were collected under fencelines and, at the East Kangaloon property, the soil under a stand of Eucalyptus fastigata was sampled. This forest soil was taken to approximate the "natural" condition.

Of the physical and chemical tests conducted on the soils, the ones likely to be affected by tillage are organic carbon (a chemical measure of organic matter) and water stable aggregates. All other information collected (exchangeable calcium, potassium and magnesium, available phosphorus, total nitrogen, pH and electrical conductivity, particle size distribution, dispersion % and Emerson's test) were used to help characterise the soil and assess potential nutrient losses through erosion.

Trial Results

Gross Margins

Potato yields in tonnes per hectare are presented in Table 3. Apart from the final year, harvestsfrom MT plots exceed those of the plots prepared conventionally on both properties. Differences in yield between plots range from 2% lower to 34% higher for MT over CT.

TABLE 3: TRIAL PLOT YIELDS (T/Ha)

	East Kangaloon			Wildes Meadow		
Year	Conventional Tillage	Minimum Tillage	% Difference	Conventional Tillage	Minimum Tillage	% Difference
92/93	35.5	39	9%	-	-	-
93/94	25*	26.6*	6%	25.2	26	3%
94/95	20.6*	31.2*	34%	33	35.8	8%
95/96	34.65	34.83	0%	25.8	25.3*	- 2%

* Only No.1 Grade Potatoes harvested. Smalls and rejects not included in the weighing.

The final year results showed little difference in yield between CT and MT. This is thought to be due to one of the coldest summers on record, which may have overridden any effects on yield due to differences in preparing the seed beds.

Table 4 presents gross margins for the harvests. The figures in the margin column are derived by subtracting the total cost of production from gross earnings (market value of the crop when bagged and ready for sale). Transport and marketing costs are not included. Margins were best in 94/95 when both market price and yields were high; 93/94 margins were low, reflecting poor yields and comparatively higher production costs associated with irrigation and extra spraying in what was a bad year for pests. Similarly, 1995/96 returns reflect the very low prices paid for potatoes. Prices were so low that only No.1 grades were marketed.

The extent to which MT gross margins exceed those of the CT plots are expressed as percentages. These figures are greater then the yield percentage differences of Table 3, reflecting the lower costs per tonne of producing potatoes using MT. The point to be emphasised here is that MT is able to yield bigger tonnages at a lower cost per tonne. This is a win-win result for the grower.

TABLE 4.GROSS MARGINS OF HARVESTS FROM PADDOCKS PREPARED CONVENTIONALLY versus MINIMUM TILLAGE.

	Conventional Tillage			Minimum Tillage			
Year	Gross Income	Product Costs	Margin	Gross Income	Product Costs	Margin	% Diff.
East Kangaloon							
92/93	$8,520	$4,002	$4,518	$9,360	$4,088	$5,272	14%
93/94	$7,500	$4,041	$3,459	$7,980	$4,091	$3,889	11%
94/95	$9,052	$3,081	$5,971	$13,728	$3,672	$10,056	41%
95/96	$5,150	$3,582	$1,568	$5,460	$3,614	$1,846	15%
Wildes Meadow							
93/94	$6,854	$3,854	$3,000	$7,330	$3,957	$3,373	11%
94/95	$13,553	$3,642	$9,911	$14,744	$3,626	$11,118	11%
95/96	$5,160	$3,837	$1,323	$5,060	$3,785	$1,275	- 4%

NB: Market Prices vary week to week, year to year. Average prices for each year were used to enable realistic dollar value comparisons to be made between trials. Prices were:

92/93 $240/T for No.1 grade. Other grades not marketed at East Kangaloon enterprise.
93/94 $300/T for No.1 grade; $80/T for Smalls; $60/T for Cocktails.
94/95 $440/T for No.1 grade; $360/T for Large; $240/T for Smalls.
95/96 $200/T for No.1 grade; Prices too low to warrant marketing of other grades.

Furthermore, where potatoes were graded from the trial plots, MT plots yielded a higher proportion of the No.1 grades over the less valuable grades. This makes the MT option even more attractive from an economic standpoint.

Soil Structure Decline

Soil tests carried out during the 3 year trial shows the impact of cultivation on soil structure. Figure 2 reveals a picture of declining 2mm aggregates, related to declining organic carbon content in soils under cultivation. Levels are declining under both MT and CT. However, the rate of decline appears to be slower in the MT plots.

More importantly, the level of reduction that has occurred in comparison to soils taken from relatively undisturbed sites (under fencelines and in the forest) has been significant. This is particularly noticeable at Wildes Meadow where the paddock used for the trial has been growing potatoes for 15 consecutive seasons. Here, the levels of organic carbon have been halved under conventional cultivation. Consequently, the percentage of 2mm aggregates has fallen from 75% in undisurbed soil (fenceline) to 18% under cultivation, with a corresponding increase in finer aggregates.

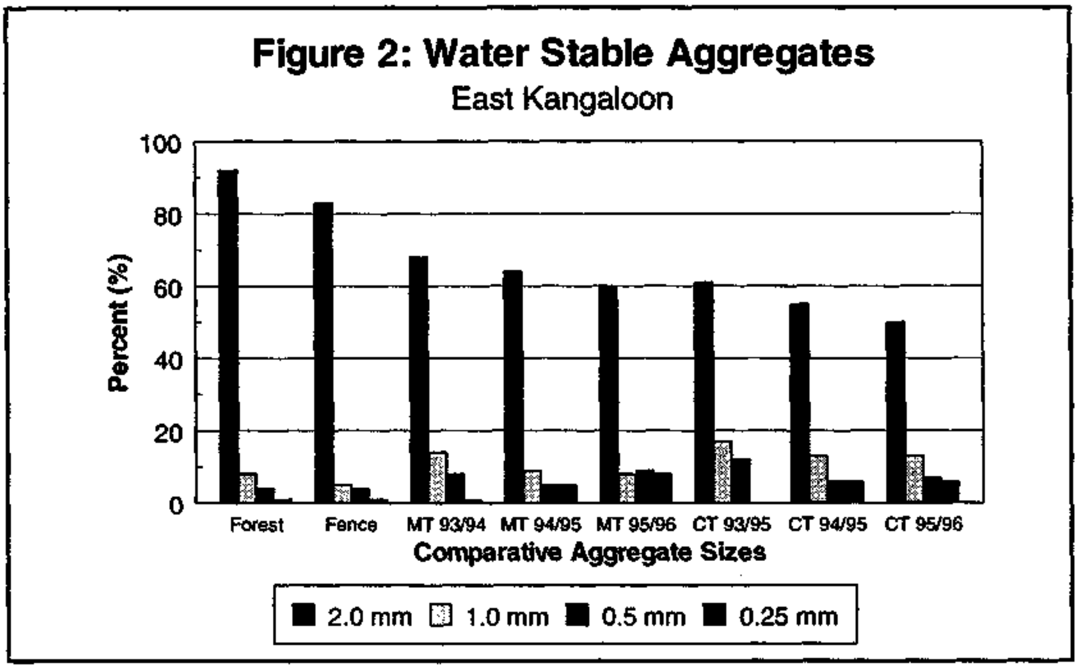


Figure 2: Water Stable Aggregates
East Kangaloon
100
80
60
40
20
0
Percent (%)
Forest
Fence
MT 93/94
MT 94/95
MT 95/96
CT 93/95
CT 94/95
CT 95/96
Comparative Aggregate Sizes
2.0 mm
1.0 mm
0.5 mm
0.25 mm

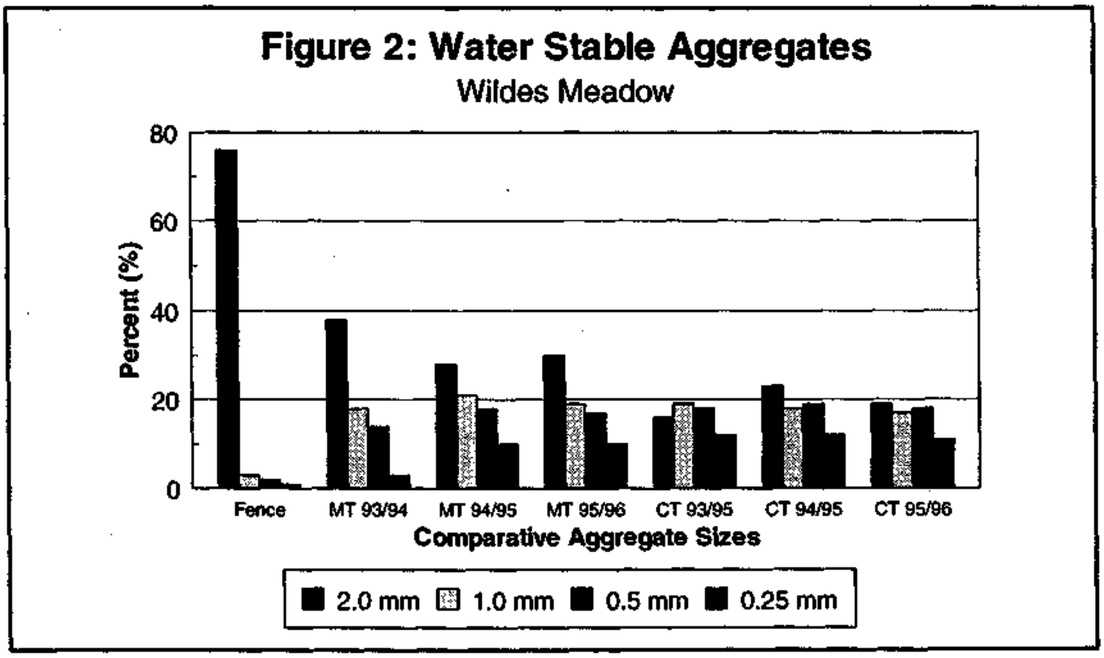


Figure 2: Water Stable Aggregates
Wildes Meadow
80
60
40
20
0
Percent (%)
Fence
MT 93/94
MT 94/95
MT 95/96
CT 93/95
CT 94/95
CT 95/96
Comparative Aggregate Sizes
2.0 mm
1.0 mm
0.5 mm
0.25 mm

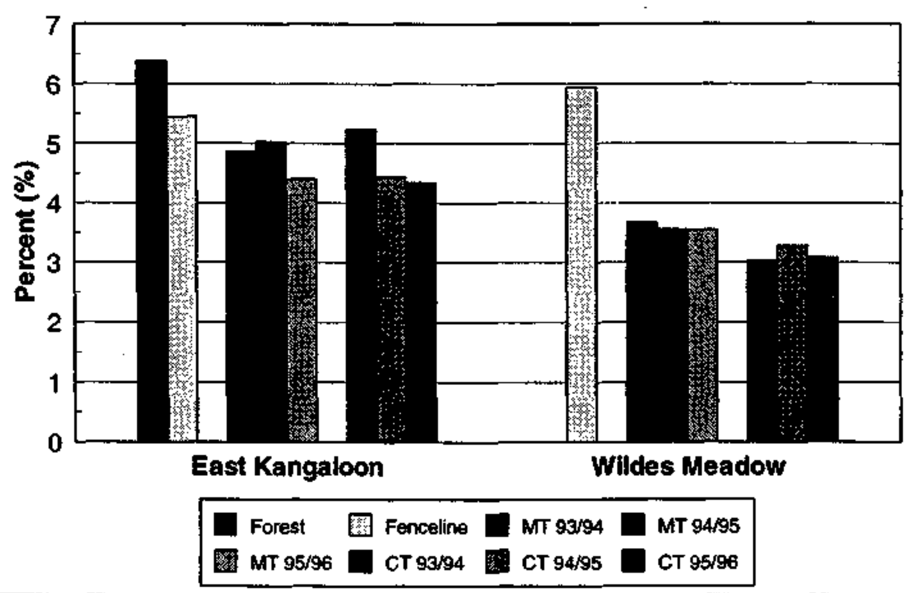
At East Kangaloon, where potatoes are grown on a 6 year rotation (3 years under potatoes followed by 3 years under pasture), the rate of decline under cultivation is more noticeable. This is because organic carbon levels are higher at the start of the 3 year potato growing phase, due to a partial recovery in levels under 3 years of pasture.

These findings bear out the comments made by growers that the risk of erosion rises dramatically under the second and subsequent crops. This can be directly related to the partial collapse of soilstructure (specifically the larger aggregates which are formed by organic matter) following the first season of cultivation. It is the reason why soils are not as "fluffy" in subsequent seasons and tend to shed water more readily.

Figure 3 supports this claim. It shows the distribution of measured aggregate sizes (or crumbs) in MT plots compared to those cultivated conventionally. It also compares these aggregate sizes with relatively undisturbed soils collected on the two properties. At East Kangaloon, results show a consistent trend of

i. declining aggregate sizes over the 3 years under potatoes,
ii. a slower rate of decline under MT
iii. significantly better proportion of the larger aggregates compared to the situation at Wildes Meadow.

Fig. 3 : Organic carbon in trial plots vs levels in undisturbed soil



At Wildes Meadow, the level of the larger aggregates are significantly reduced due to the many years of continuous cropping. There is no real trend evident over the sampling period, either up or down, probably because the situation has bottomed out. Nevertheless, marginally higher levels of the 2mm aggregates in the MT plots suggest there is some recovery going on. Indeed, the amount of sediment deposited at the foot of the MT rows following a 120 mm downpour in April, 1996 was noticeably less than was washed off the CT plots.

Green Manuring

In Robertson, raising cattle forms a valuable component of most farming enterprises. By and large, pastures and cover crops grown between potato crops are grazed. Rarely are they ploughed in to benefit the soil (ie green manure cropping). There is understandable resistance to ploughing in a valuable fodder crop even though studies have shown increased yields in subsequent potato crops. The resistance is due to the high cost of rural land ($10,000/ha) in the area which makes it imperative that land is used to its full potential.

Nevertheless, with roughly one third of the organic matter of a plant being below ground (ie the root system), the soil will still benefit significantly from the practise of establishing cover crops between successive potato crops. It is essential that a cover crop of some kind be established as soon as possible after completion of harvesting.

Recommendations

The work over the last few years has demonstrated the effectiveness of a number of simple strategies growers can adopt to reduce the risk and severity of erosion and sedimentation. The following points summarise this strategy in a nutshell -

- Avoid steep slopes (>20%)
- Stay out of natural water courses, use these as water disposal areas.
- Divert external run off using diversion banks.
- Control in-crop runoff by a combination of graded banks and plough drains.
- Trap any sediment onsite - direct all runoff from the crop through sediment trap(s).
- Adopt mimimum tillage practices, less distructive on soil and makes economic sense.
- Avoid excessive number of consecutive crops.
- Avoid excessive compaction and trafficking, deep rip compacted areas prior to sowing.
- Sow cover crops <u>immediately</u> after harvest.

Nutrition Management Strategies For Sustainable Potato Production.

by
Sandra M. Lanz
Project Co-ordinator

Contents:

Introduction

In 1991 the Robertson District Potato Advancement and Landcare Association (RDPA&LA) began working with the Department of Land and Water Conservation, NSW Agriculture and Sydney Water to address the issue of sediment run off from cultivated potato cropping land. This was a major issue for the growers because of their location in the Sydney / South Coast water supply catchments.

The growers addressed this issue through the implementation of soil management strategies (see Chapter 1, Strategies for Sustainable Land Management). By implementing such strategies growers lost 15 - 20% of cropping land area. This led growers to investigate ways of recouping this loss by increasing yield and decreasing costs. The RDPA&LA also wanted to continue and strengthen their role as environmentally conscious farmers and ensure the issue of water quality down stream did not stop with the implementation of land management strategies. This led to the development of a nutrient monitoring program, and demonstration trials in order to determine the most appropriate nutrition or fertiliser program for growers.

The Problems.

Potato growers in the Robertson district have traditionally applied 2.5 t/ha (1 t/acre) of "Robbo" special at planting. This is a fertiliser mix of 5% nitrogen, 7% phosphorus and 5% potassium. Other mixes are used and generally consist of similar proportions of nitrogen, phosphorus and potassium.

This method has served growers well however with the issue of nutrient movement off site, increasing costs of production, decreasing returns and availability of suitable cropping land growers wanted to refine their crop nutrition strategies. It is also known that other growing districts use half the amount of fertiliser to grow crops of higher tonnage. The Robertson growers wished to discover why their soils were so hungry.

During the first season of the project soil and plant testing were undertaken throughout the district as well as a small demonstration trial looking at different fertiliser mixes. From this work the following areas were highlighted as the main issues confronting the Robertson growers in regards to crop nutrition:

- Soil acidity.
- High soil phosphorus levels.
- Low potassium levels in plant tissue late in the season.
- Low soil magnesium levels.

Solutions

A - Monitoring program:

The monitoring program consisted of soil testing and plant testing for the major and minor nutrients, and comparing the results with standards being developed in South Australia as part of the project PT428 "Information packages and decision support software for improved nutrient management of potato crops". Soil test results were compared to standards developed through research carried out in Tasmania, South Australia and Victoria.

Each participating grower identified at least 2 crops to be monitored in this fashion. Before the season a soil test was taken and sent to Incitec laboratories at Port Kembla. A full horticultural test plus colwell K and Bray P was carried out. The cost for this test varied over the duration of the project from $110 to $92 depending on the agent used.

Once results had been received the grower discussed them with the Industry Development Officer to determine the most appropriate fertiliser program to follow.

During the growing season 2 full dry matter nutrient analyses were taken. One early in the season and one when the crop was reaching maturity. The petiole samples were sent by airmail to CSBP laboratories in WA. The cost was $30 per test. Results were faxed and posted within 7 working days. These results were then graphed to indicate to growers the trend over the season of the nutrient concentrations within the plant. These results were compared to standards developed by research in South Australia.

In 1992 the RDPA&LA undertook a study tour of South Australia to look at land management and production methods of potatoes in that state. During the tour the RDPA&LA purchased a sap nitrate testing kit. This kit has been used to gather information regarding plant nitrogen status. Petiole samples were taken 3 to 4 times early in the growing cycle of the crop to determine the crop nitrogen status. These results were plotted on graphs developed by Chris Williams and Norbert Maier from the South Australian Department of Primary Industries, indicating if nitrogen was in excess, adequate or lacking to ensure maximum yield potential. These results were then compared with the dry matter total nitrogen and dry matter nitrate results received.

How to Take a Soil test:

To get a true indication of the paddock it is necessary to:

- Take approximately 40 samples or soil cores of approximately 15cm deep.
- To walk diagonally across the paddock or do a zig zag across the paddock to collect the sample.
- Place cores into a clean bucket mix them well.
- Take a sample of approximately 500g label and send to the laboratory.
- Often you will find that your fertiliser sales person is happy to take this sample for you.

Plant Tissue Testing:

The Process of plant tissue testing is very similar to that of soil sampling. However it is very important that the correct plant part is taken. To ensure you know which part to sample please contact your local consultant, fertiliser representative, merchandise agent or Department of Agriculture Officer.

Results:

Over the duration of the project a total of 78 crops were monitored in relation to nutrition. All the data for each nutrient was plotted onto graphs to determine if any district trends existed, this also highlighted differences between seasons (see Fig.1).

For example dry matter potassium for all 3 years monitored shows levels within or above those recommended for the first sampling. At the 2nd sampling stage levels had dropped. In 1995/96 these levels had dropped considerably more than the previous 2 seasons, particularly when compared to 1993/94. This would be a reflection of rainfall and irrigation practices. In 1993/94 and 1994/95 the Robertson district experienced drought. In 1994/95 growers were more attune to irrigation needs of their crops, and so more water was applied compared to 1993/94.

This suggests that potassium applied at planting was being leached due to high applications of water. This information suggests that in wet years potassium should have split applications, 1/2 to 3/4 at planting and the balance no later than hilling.

Sap nitrate and dry matter nitrate early in the season often indicated low levels of nitrogen in the plant. This could be due to the cooler temperatures experienced early in the season. This trend was pronounced in 1995/96 which was a very cold season. These results indicate to growers that the form of nitrogen applied can be very important early in the season.

B - Comparative Analysis:

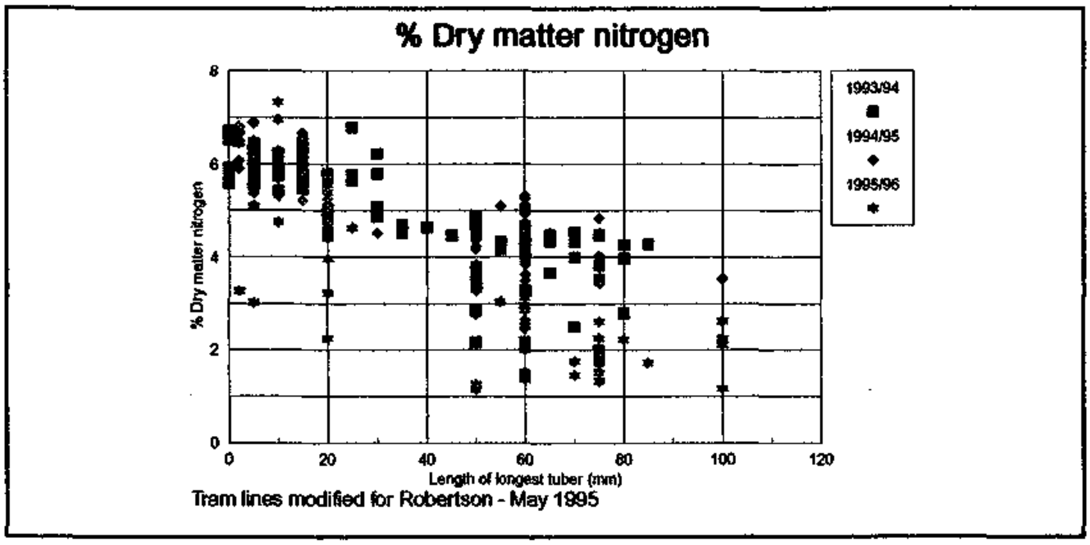
Information regarding all aspects of crop production were kept by growers. This was done to help determine the most appropriate and cost effective crop management program. Table 1 details the information collected. A copy of the record keeping booklet can be found in Chapter 7. At the end of each season an estimate of yield was conducted.

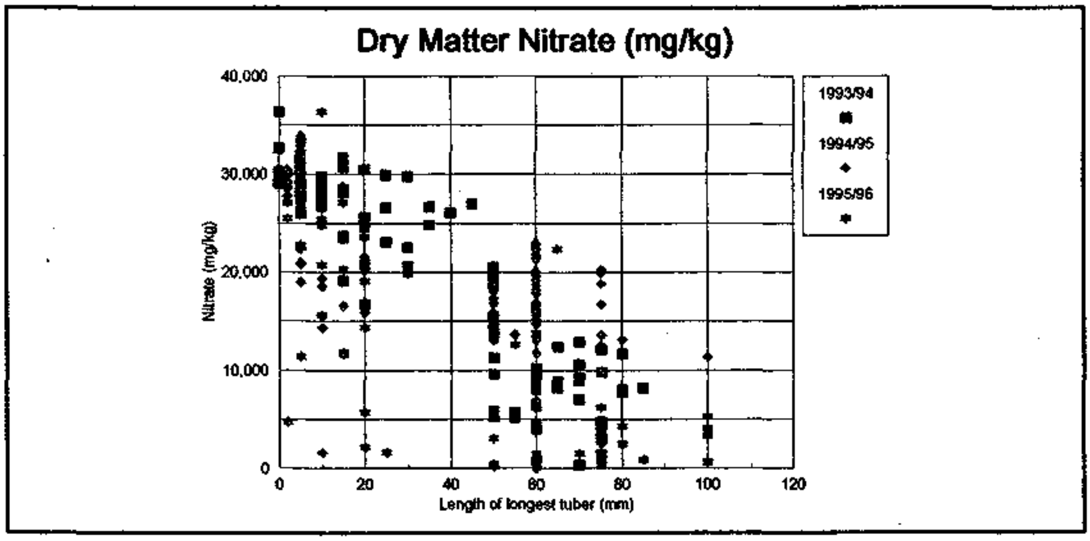
From this table growers are able to see what each person did regarding the management of their crop. This information can be used to determine the cost of inputs versus the final yield or return. Growers are also able to compare their practices with practices undertaken to produce the highest yielding crop. By doing this growers may develop different strategies in order to improve yield. For example, those crops which had a greater number of irrigations tended to show better yields.

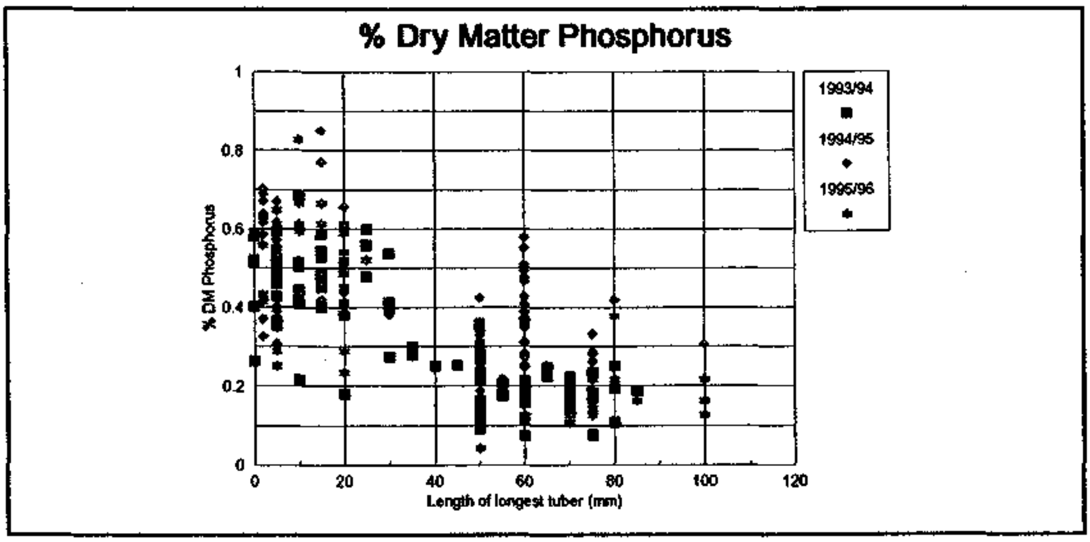
Table 1: Comparative Analysis Records

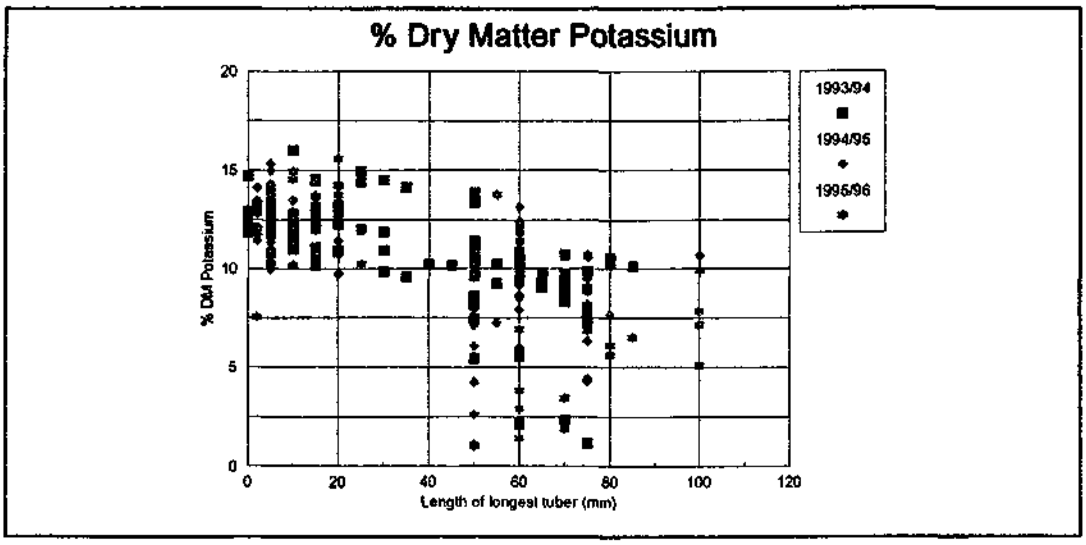
Crop No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Variety	Sebago	Pontiac	Sebago	Pontiac	Atlantic	Atlantic	Sebago	Atlantic	Atlantic	Sebago	Sebago	Sebago	Sebago	Sebago	Sebago	Sebago	Sebago
Paddock	1	Tower	Tank	Mrs B's	Jack's House	Avoca	Henderson	Pdk 1	Pdk A								
Area (ha)	4 ha							5ha	7 ha								
Slope	moderate to steep	steep	moderate	steep	steep	undulating	steep	gentle	undulating	steep	steep	steep	steep	steep	steep	steep	undulating
Contour drains	none	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes
Years since last potatoe	3	1	?	1	1	many	1	15	1	1	1	1					
Previous crop	grass	oats	pasture	oats	oats	pasture	oats	pasture	oats	oats	oats	oats	pasture	pasture	pasture	pasture	oats
SEED / PLANTING																	
source	crookwell	own	own	crookwell						own	own	own	Crookwell	Crookwell	Crookwell	Crookwell	Crookwell
generation	certified	G4	G4	G5						G6	G6	G6	certified	certified	certified	certified	certified
dust applications								mancozeb	mancozeb	rizolex	rizolex	rizolex	rizolex	rizolex	rizolex	rizolex	mancozeb
spray applications		rovral	rovral	rovral	rovral	rovral	rovral	rovral	rovral	no	no	no	no	no	no	no	rizolex
days cut before planting	1	1	1					1 - 2	1 - 2	1	1	1	1	1	1	1	1
seed spacing	9 inches	9 inches	9 inches	9 inches	9 inches	9 inches	9 inches	9 inches	9 inches	10 inches	10 inches	10 inches	10 inches	10 inches	10 inches	10 inches	10 inches
seed depth	4 inches	4 inches	4 inches	4 inches	4 inches	4 inches	4 inches	4 inches	4 inches	4 - 6 inches	4 - 6 inches	4 - 6 inches	4 - 6 inches	4 - 6 inches	4 - 6 inches	4 - 6 inches	6 inches
date of planting	29/8/94	September	October	September	Oct	Nov	Dec	mid Nov	late Nov	24/10/94	24/10/94	24/10/94	30/11/94	30/11/94	30/11/94	30/11/94	early Dec
date of emergence	14/10/94								13/12/94	18/11/94	18/11/94	18/11/94	18/12/94	18/12/94	18/12/94	18/12/94	
date of hilling										5/12/94	5/12/94	5/12/94	19/1/95	19/1/95	19/1/95	19/1/95	
Soil preparation	2 rotary hoe	chisel plough	spray	hoe	hoe	hoe	hoe	rotary hoe	disc	agroplow	agroplow	agroplow across	ripped	agroplow across	agroplow across	agroplow across	agroplow
	chisel plough	power harrow	rotary hoe	chisel	plough	plough	plough	agroplow	agro plow	disc x 2	disc x 2	contour	disced	contour	contour	contour	with hilling
	deep rip		agro plough	tynes	tynes	tynes	tynes	rotary hoe	rotary hoe	ripped	ripped	planted	agroplow	ripped	ripped	ripped	tynes
	rotary hoe		power harrow							agroplow +	agroplow +		plant	planted	planted	planted	
										power tynes	power tynes		scarify x 2	scarified x 2	scarified x 2	scarified x 2	
										plant	plant		harrowed	harrowed	harrowed	harrowed	
										scarify x 2	scarify x 2		hilled	hilled	hilled	hilled	
										harrow	harrow						
										hilled	hilled						
Fertiliser	2 t/ha, 5:7:5	2.5 t/ha 5:6:4 or	2.5 t/ha 5:6:4 or	2.5 t/ha 5:6:4	2.5 t/ha 5:6:4	2.5 t/ha 5:6:4	various	2.4 t/ha 5:7:5	2.4 t/ha 5:6:4	2.5 t/ha 5:7:5	2.5 t/ha 5:7:5	2.5 t/ha 5:7:6	2.5 t/ha 5:7:5	2.5 t/ha 5:7:5	2.5 t/ha 5:7:6	2.5 t/ha 5:7:6	5:7:5
		1.25 t/ha 0:14:0	1.25 t/ha 0:14:9							Humic acid					Promesium hi	Promesium low	
Irrigation	applications, gun	> 4 applications	4 applications	7 applications	4 applications	2 applications	2 applications	4 applications,	5 applications				2 applications	2 applications	2 applications	2 applications	1.5 inches
			of 2 inches					total 220 mm	total 276 mm				of 50 mm	of 50 mm	of 50 mm	of 50 mm	only once
Rainfall	162 mm	not recorded	not recorded	not recorded	not recorded	not recorded	not recorded	not recorded	not recorded								
Spray program	spray seed	azodrine x 4	azodrine x 2	rovral x 1	foli R fos	none	none	spray seed	spray seed	birlane	birlane	birlane	birlan x 3	birlan x 3	birlan x 3	birlan x 3	spray seed
			antracol x 1					score	score x 2	score	score	score	score	score	score	score	
								rovral	grammaxone	birlane	birlane	birlane	antracol	antracol	antracol	antracol	
								chlorothanolil	reglone	antracol	antracol	antracol					
								antracol	chlorothanolil								
								nitofol 580	antracol x 2								
								nuquat	nitofol 580								
									nuquat								
									reglone								
Yield	39.65 t/ha	33 t/ha	30.4 t/ha	47 t/ha	35.25 t/ha	30 t/ha	43 t/ha	56.9 t/ha	42 t/ha	50 t/ha	45 t/ha	38.5 t/ha	20.8 t/ha	24.3 t/ha	24.1 t/ha	27.4 t/ha	51.5 t/ha

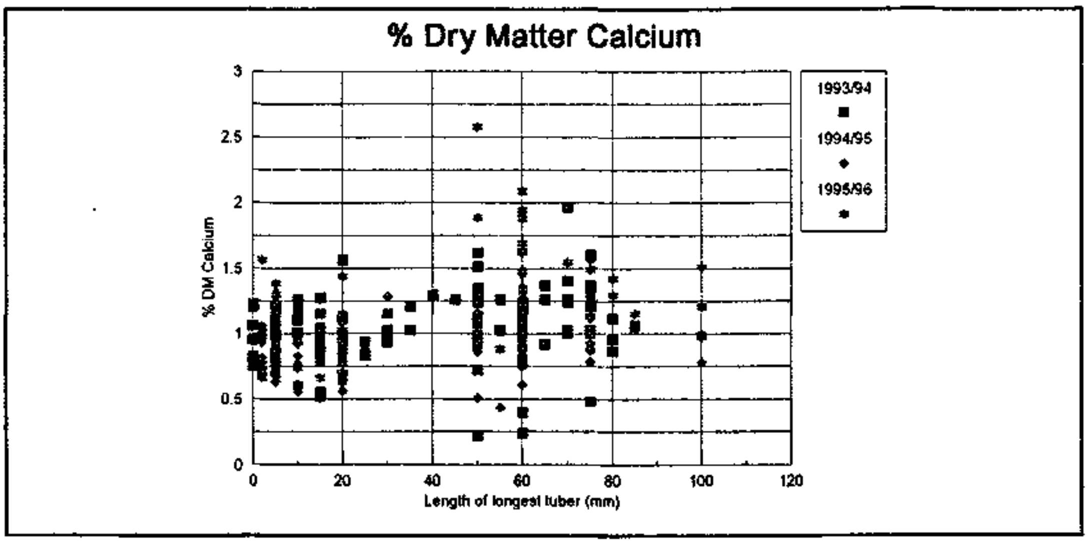
Figure 1 : Dry Matter Nutrient Results

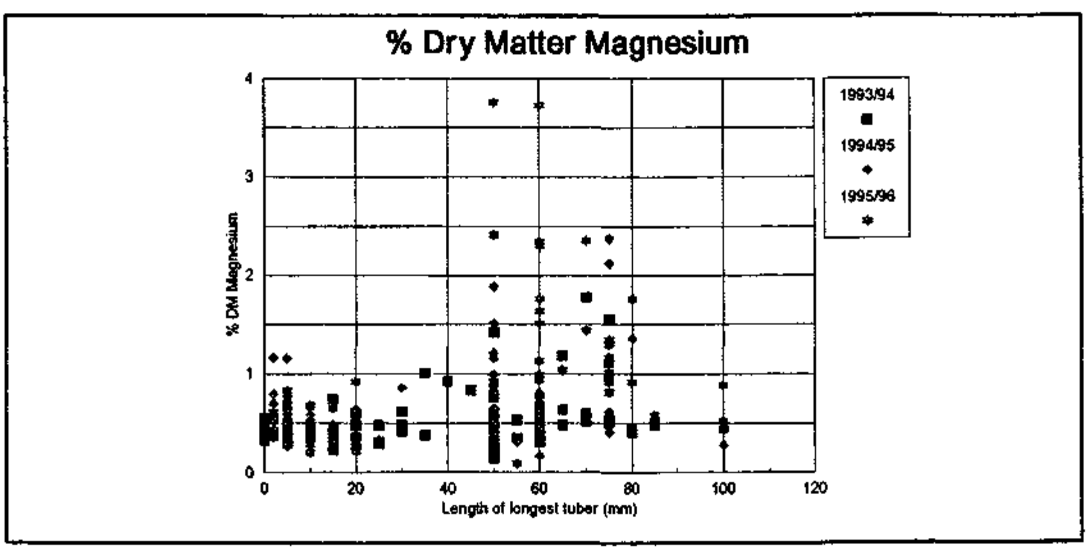







% Dry Matter Potassium
% DM Potassium
Length of longest tuber (mm)
1993/94
1994/95
1995/96


% Dry Matter Calcium
% DM Calcium
Length of longest tuber (mm)
1993/94
1994/95
1995/96


% Dry Matter Magnesium
% DM Magnesium
Length of longest tuber (mm)
1993/94
1994/95
1995/96

C - Demonstration Plots:

A great deal of research has been carried out throughout Australia and overseas in relation to potato crop nutrition. The RDPA&LA wished to use this research to ensure they produce good yielding, high quality sustainable crops.

One of the major reasons nutrition has become an important issue to Robertson growers is because they are in the Sydney, South Coast water catchment areas. The growers in the district have addressed the issue of soil run off now they want to ensure they minimise the use of fertiliser and so minimise nutrient run off

The planting season in the Robertson district begins in late August and finishes late December to early January depending on the season and water availability. Growers in the district tend to feel the best crops are produced from an October planting.

In the first year of the project a number of commercial mixes were investigated. These mixes were applied at varying rates in order to determine the best rate for Robertson conditions.

As a result of the fertiliser investigations during the first season and discussions with specialists from the USA and South Australia it was identified that phosphorus, potassium, pH, and magnesium are areas where further investigation should take place.

The following discussion outlines the investigations undertaken in the second and third seasons of the project to address issues highlighted by the first season.

Harvesting of fertiliser demonstration trial and grading of tubers.

1 - Phosphorus, Potassium and Magnesium demonstration.

Background
Phosphorus contributes to the early development and tuberisation of a potato crop. Phosphorus is not readily leached from the soil, however in the Robertson red soils it is fixed to soil particles very easily and so becomes unavailable to the plant. It is for this reason that growers in the Robertson district apply large quantities of phosphorus fertiliser.

Potassium is important in sizing of tubers and also influences tuber quality factors such as specific gravity, after cooking darkening, black spot bruise, and storage quality. Growers in the Robertson district traditionally apply all potassium fertiliser at planting.

Magnesium is known to aid in the uptake of phosphorus. Soils in the Robertson district are often low in magnesium, dolomitic limestone is often applied to improve magnesium levels and to increase soil pH.

The Demonstration Trial
The Donovan and Hill families provided sites where the fertiliser demonstration plots could be located.

A soil test was taken for each site, the results are detailed in Table 3. Treatments were developed using soil test results, dry matter nutrient results from the previous season and discussions with US and South Australian specialists (see Table 2).

W.Paton fertilisers Pty Ltd provided the growers with the appropriate mixes for the test plots and included a recommendation of their own, which was a low phosphorus application.

Each treatment consisted of 4 rows.

Atlantic was planted at the Donovan site and Sebago was planted at the Hill site.

Each treatment was located as not to be affected by spray rows.

Irrigation, pest and disease management was undertaken by the grower.

Two dry matter tissue samples were taken during the growing season and three sap nitrate tests were carried out for each treatment at each site.

Each treatment was split in two and an application of promesium which is a source of magnesium was applied at 2.5t/ha (1t/acre) this is equivalent to 670 kg/ha of magnesium. The promesium application was made in year 1 only.

At the end of the season yield estimates were undertaken at each site for each treatment. The yield estimates comprised of 5m from the 2 centre rows of each treatment. Tubers were weighed giving total yield and then graded into <50mm, 50-85mm, 85-95mm and >95mm using sizing rings and weighed again.

1994/95

Treatments 1- 8 at the Donovan site had a base application of 5:7:5 at a rate of 2.5 t/ha which was banded at planting.

For treatment 5 and 6 the extra potassium (K) was broadcast before planting.

For treatment 7 and 8 the extra phosphorus (P) was broad cast before planting at the Donovan site and at the Hill site a special blend was used containing extra P with equivalent K and N..

Treatment 9 and 10 at the Hill site was a special low P blend applied at planting. Treatments 9 and 10 at the Donovan site consisted of 170kg/ha of muriate of potash spread before planting, 1200 kg/ha of 5:7:5 banded at planting and 200 kg/ha of urea side dressed at 1st tuber.

1995/96

The same rates for each nutrient was applied in 1995/96, except that it was all pre-mixed and applied at planting.

No promesium was applied in 1995/96. Plots were still divided into (+) and (-) magnesium to determine what differences appeared over time.

Table 2 : Fertiliser test plot treatments.

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	Mg (kg/ha)
1. Control	0	0	0	0
2. Control +Mg	0	0	0	670
3. Normal application	125	175	125	0
4. Normal application +Mg	125	175	125	670
5. Increased K level	125	175	300	0
6. Increased K level +Mg	125	175	300	670
7. Increased P level	125	270	125	0
8. Increased P level +Mg	125	270	125	670
9*. W.Paton recommendation	125	50	125	0
10*. W.Paton recommendation +Mg	125	50	125	670
9#. W. Paton recommendation	152	85	145	0
10#. W.Paton recommendation +Mg	152	85	145	670

* W.Patons recommendation for the Hill site. # W.Patons recommendation for the Donovan site.

Table 3 : Soil test results.
Hill Site

	Hill 1,993	Hill 1,994	Hill +Mg 1995	Hill -Mg 1995
Soil colour	red brown	yellow,brown	yellow, red	yellow, red
Soil texture	gscl	gcl	clay, loam	clay, loam
pH (water)	5.1	5.4	5.4	5
pH (CaCl)	4.6	4.9	4.7	4.6
Buffer pH	6.3			
Organic C %	3.6	4.3	3.8	3.3
Nitrate nitrogen mg/kg	36	12	13	10
Sulfate sulfur mg/kg	350	379	295	299
Phosphorus(Colwell) mg/kg	296	228	317	211
Phosphorus (Bray) mg/kg	87	33	25	10
Potassium(Colwell) mg/kg		197	225	228
Potassium meq/100g	0.7	0.7	0.5	0.5
Calcium meq/100g	5.5	7.7	4.7	4.7
Magnesium meq/100g	1.2	2.1	2.6	1.9
Aluminium meq/100g	0.8	0.21	0.5	0.58
Sodium meq/100g	0.7	0.06	<0.05	<0.05
Chloride mg/kg	15	15	<5	<5
EC dS/m	0.31	0.21	0.13	0.12
Copper mg/kg	2.4	2.8	2.5	30
Zinc mg/kg	1.6	1.7	1.6	1.2
Manganese mg/kg	12	11	8	8
Iron mg/kg	57	76	50	39
Boron, mg/kg	1.2			
Cation exchange meq/100g	8.3	10.8	8.4	7.7
Ca/Mg ratio	4.6	3.7	1.8	2.5
Aluminium saturation %	9.6	1.9	6	7.5
Sodium % of cations	0.8	0.6		
EC (se) dS/m	2.7	1.7	1	1

gscl = gravelly, sandy, clay loam.
gcl = gravelly, clay loam.

Donovan Site

	93/94	94/95, + Mg	94/95, -Mg
Soil colour	brown	yellow, brown	reddish brown
Soil texture	sandy,clay,loam	clay, loam	vfs,c,l
pH (water)	5.4	5.8	5.6
pH (CaCl)	4.8	4.9	4.9
Buffer pH			
Organic C %	3.2	6.8	7.3
Nitrate nitrogen mg/kg	9	13	10
Sulfate sulfur mg/kg	20	37	24
Phosphorus(Colwell) mg/kg	97	123	123
Phosphorus (Bray) mg/kg	36	55	46
Potassium(Colwell) mg/kg	75	84	92
Potassium meq/100g	0.1	0.1	0.2
Calcium meq/100g	5.2	5.6	5.3
Magnesium meq/100g	1	1.5	1
Aluminium meq/100g	0.32	0.06	0.3
Sodium meq/100g	<0.05	0.05	<0.05
Chloride mg/kg	22	7	<5
EC dS/m	0.05	0.06	0.06
Copper mg/kg	<0.5	0.6	2.7
Zinc mg/kg	1.3	0.8	1.7
Manganese mg/kg	3	2	2
Iron mg/kg	187	97	152
Boron, mg/kg			
Cation exchange meq/100g	6.7	7.3	6.8
Ca/Mg ratio	5.2	3.7	5.3
Aluminium saturation %	4.8	0.8	4.4
Sodium % of cations			
EC (se) dS/m	0.4	0.5	0.5

vfs,c,l = very fine sandy clay loam.

Results:

- At both sites for both seasons a yield response was recorded when fertiliser was applied.

- Increased applications of phosphorus at both sites for both years gave the highest yield except for the Donovan site in 1994/95.

- At the Donovan site, added magnesium tended to depress yield slightly for most treatments in both seasons.

- In 1994/95 at the Hill site applications of magnesium notably increased yield in all treatments, except for the control. This was not reflected in 1995/96.

- Higher applications of potassium at planting did not help to increase yield compared to other treatments.

- Plant potassium levels dropped more dramatically at the Donovan site compared with the Hill site, this could be related to soil type and the cation exchange capacity of the soil.

- The normal application of 5:7:5 plus added magnesium rated in the top 5 yield results in 1994/95 at both sites and in 1995/96 at the Donovan site.

- Magnesium uptake at the Donovan site was shown to be much greater than at the Hill site. The reason for this is unknown but may be related to soil moisture, paddock history and soil type.

- Dry matter results showed all treatments to follow similar trends throughout the season. Control treatments always showed lower levels compared to other treatments.

Figure 2: Yield Results for 1994/95

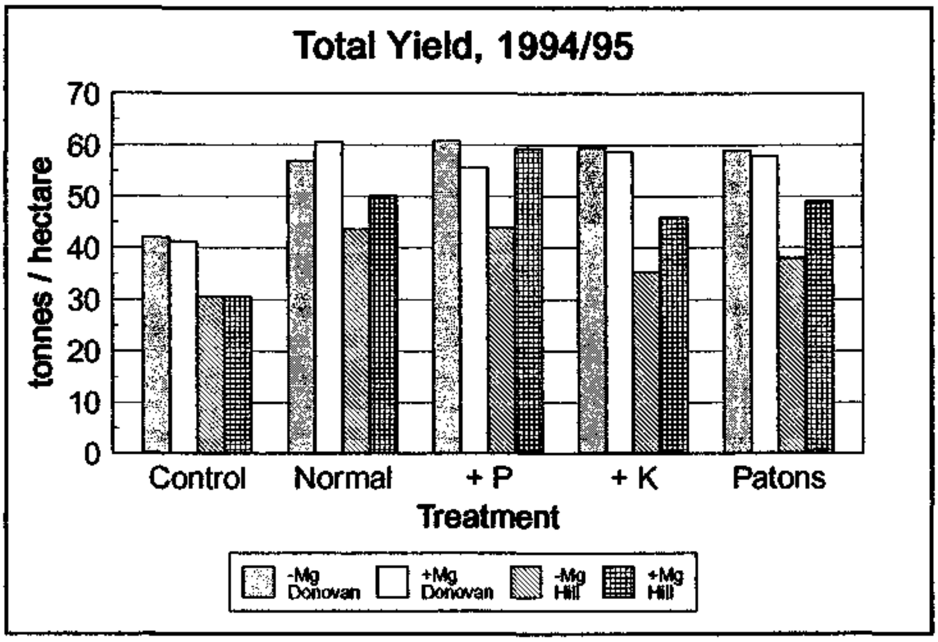
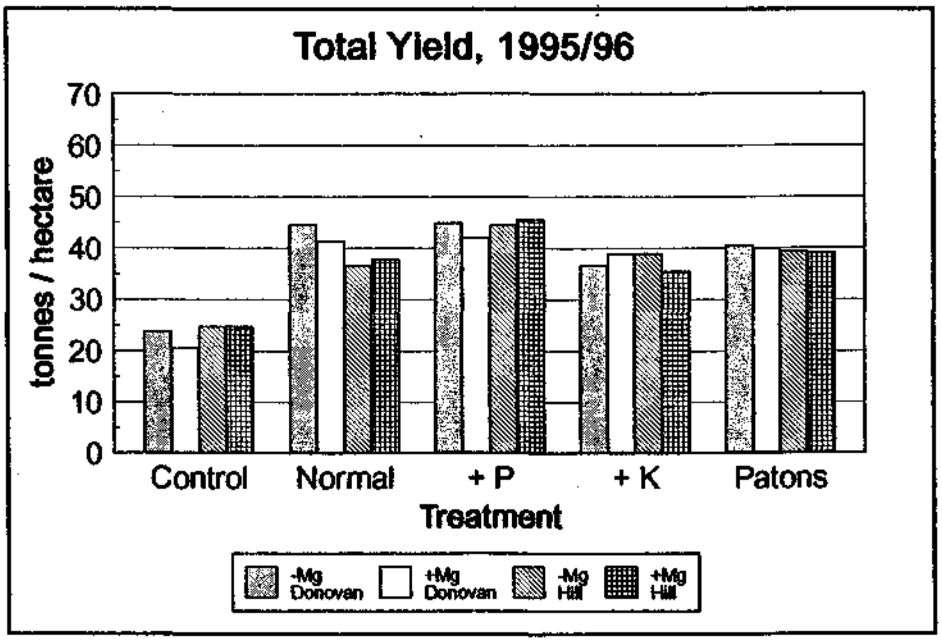


Figure 3: Yield Results for 1995/96



Recommendations:

- Continue to take soil and plant tissue tests to build up a data base, with the aim of developing accurate interpretation of results for this district.

- Pre plant broad cast applications of potassium do not appear to be an appropriate method to increase yield for this district. A split application of potassium may be more appropriate. This may be achieved by applying 1/2 potassium at planting at 1/2 potassium at hilling as a side dressing or foliar application.

- Investigate further appropriate phosphorus application rates and management strategies with the aim of improving availability of phosphorus for plant uptake.

- With high soil phosphorus levels (> 200ppm, Colwell) applications of between 100 and 175 kg of phosphorus per hectare should be investigated.

- It is important to maintain soil moisture throughout the season to ensure optimum conditions for plant nutrient uptake, especially phosphorus.

- The results from the demonstration plots indicate fresh applications of magnesium improve crop yield where high soil phosphorus levels are experienced.

2 - Soil Acidity Amendment Demonstration:

At the completion of the 1993/94 season a trend was found showing low pH throughout the district and lock up of soil phosphorus. This soil lock up is not unusual in acid soils. From this work it was determined that the group would look at different rates of liming materials and also a granular humic acid, (see Table 4), with the aim of increasing pH and so increase the availability of soil phosphorus.

Table 4 : Soil acidity amendment treatments.

No	Treatment	Rate
1	Doly dust	2.5 t/ha
2	Doly dust	5 t/ha
3	Control	0 t/ha
4	Lime	2.5 t/ha
5	Lime	5 t/ha
6	Granular humic acid	200 kg/ha
7	Granular humic acid plus Doly dust	200 kg/ha plus 2.5 t/ha

Treatments were applied to an area of approximately 10 rows by 50 m. Soil samples were taken before treatments were applied to determine pH, samples were taken at the end of the first season and at the end of the second season to determine how pH had changed.

Lime was used as the standard. Doly dust, a by - product from the Port Kembla steel works, was used because growers commonly use it instead of dolomite. Table 5 below gives a comparison between lime, dolomite and doly dust. Granular humic acid was applied because research in the US has shown it to be a useful soil pH ameliorant.

Table 5 : Lime vs Dolomite vs Doly Dust

	Lime[1] (pure)	Dolomite[1] (pure)	Doly[2] dust
[3]Neutralising value	100	109	120
[3]Ca %	40	21	22
[3]Mg %	0	13	12

[1]Agfacts, NSW Agriculture, Soil acidity and liming., First edition 1993
[2]Reme Pty Ltd, soil environmental analysts, plus a product sheet received from BHP.

[3]Please note that high values can be expected only from fresh lime. Burnt and hydrated lime, dolomite and magnesite readily react with carbon dioxide and moisture in the atmosphere to revert to hydrated and carbonate forms causing their neutralising value and calcium and magnesium analyses to fall with time and exposure to air.

Results

- All soil amendment treatments increased pH (see Figure 4).

- The 5 t/ha of Doly dust and lime increased pH to a greater extent in the first year when compared with the 2.5 t/ha application rates. In year 2 the 2.5 t/ha application rate of Doly dust gave a higher pH reading than the 5 t/ha application rate. Both Doly dust treatments had increased pH from year 1. The 2.5 t/ha application of lime in year 2 recorded a pH the same as the 5 t/ha lime application (see Figures 5 & 6).

- These results indicate that there is little advantage in applying 5 t/ha of lime or Doly dust compared to the 2.5 t/ha (see Figure 4).

- Granular humic acid applied at the recommended rate of 200kg/ha increased pH. There appears to be a synergistic effect between granular humic acid and Doly dust. This is indicated by treatment 7 showing the greatest increase in pH compared to all other treatments in both years.

- Results indicate that pH does not have a great effect on yield. As can be seen in Figures 5&6 the control treatment at pH 4.9 gave the 2nd highest yield both years. This indicates that other factors are influencing yield apart from pH. These factors may include soil moisture, disease, and pest pressures.

Recommendations:

- This strip trial has only been monitored for 2 years the effects of liming soils have a much longer time scale. Potatoes are fairly tolerant of acid soils and it may be the secondary effects liming has on the soil which influences the yield and quality of a potato crop.

- The RDPA&LA will be undertaking a more in depth study over the next 3 years looking at phosphorus management strategies on kraznosem soils. Increasing organic matter and different application rates of doly dust will be the major treatments investigated.

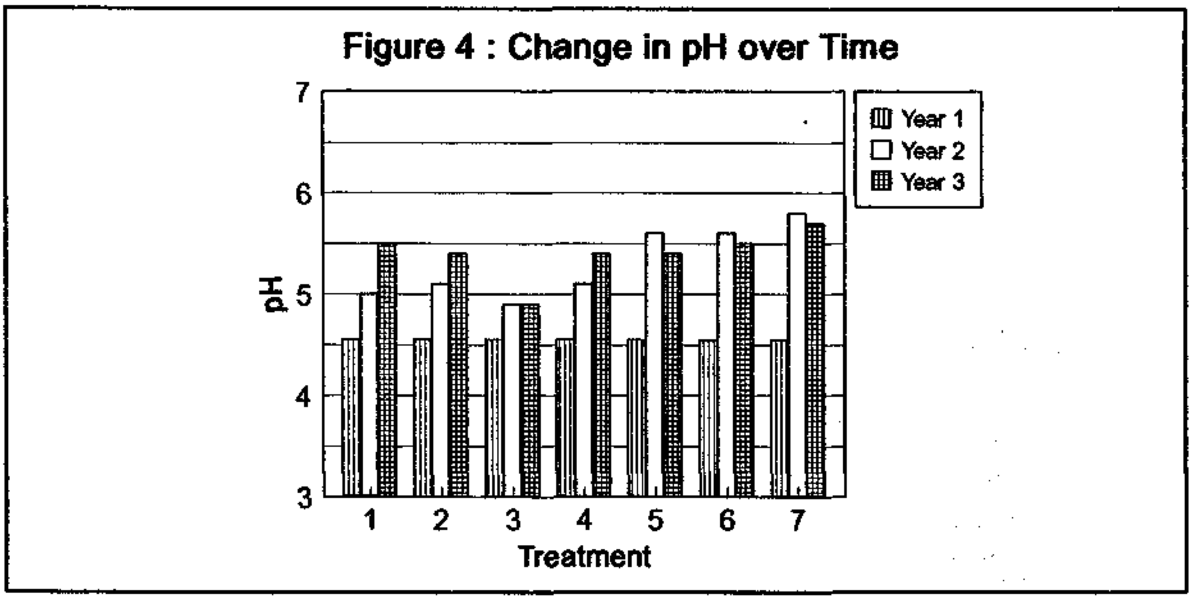


Figure 4 : Change in pH over Time
Year 1
Year 2
Year 3
pH
7
6
5
4
3
1
2
3
4
5
6
7
Treatment

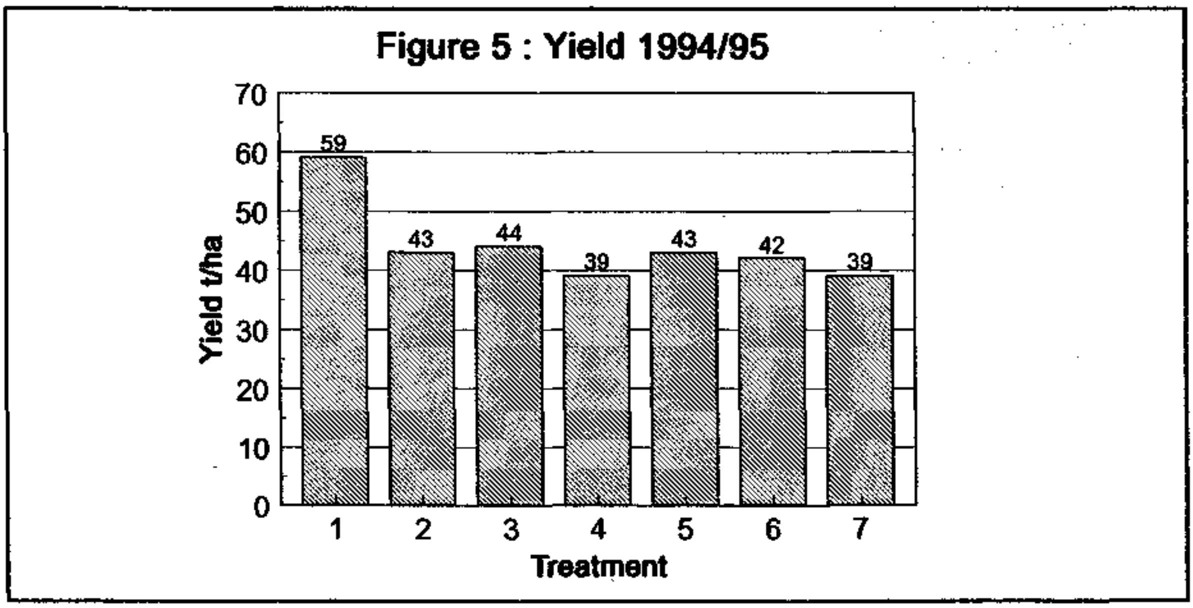


Figure 5 : Yield 1994/95
Yield t/ha
70
60
50
40
30
20
10
0
59
43
44
39
43
42
39
1
2
3
4
5
6
7
Treatment

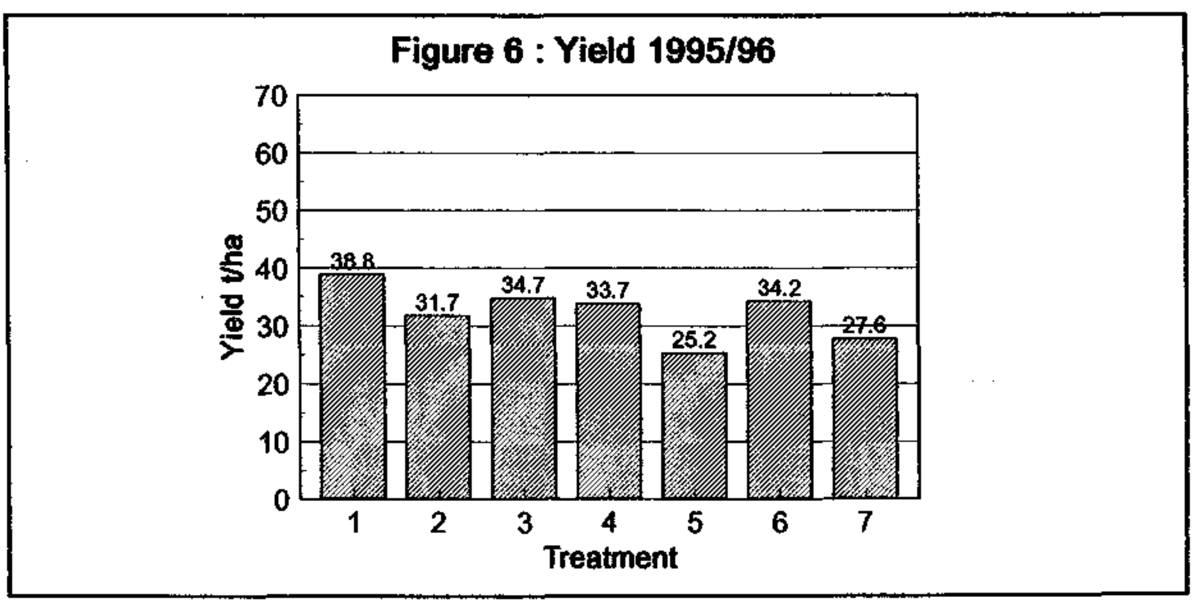


Figure 6 : Yield 1995/96
Yield t/ha
70
60
50
40
30
20
10
0
38.8
31.7
34.7
33.7
25.2
34.2
27.6
1
2
3
4
5
6
7
Treatment

Sustainable Irrigation Management in Potatoes

by
Mike Robbins
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Contents:

Introduction

The Robertson area is located in the Central Highlands of NSW and is one of the main areas of potatoes to the ware and processing industries in the State.

The area has an annual rainfall of a 1650 mm, with the monthly average ranging between 175 mm in March to a low of 80 mm in August, while the annual evaporation is about 1000 mm. The area is divided into many micro - climates with each bearing no resemblance to the next as far as rainfall and evaporation is concerned.

The soils on which the potato crops are grown are predominantly deep red Krasnozem light clay loams, with water holding capacities in the region of 175 mm/m. The topography is ridging, with the farming operations being undertaken on moderate to steep slopes. The areas planted to potatoes are rotated on a regular basis to minimise disease problems.

Irrigation has traditionally been undertaken utilising soft and hard hose travelling irrigators, and hand shift irrigation pipes with the supply of water for each area being from small gully dams. Portable pumping units powered by diesel engines or tractors are used to supply water to the irrigation systems. These irrigation systems are moved from paddock to paddock

The farmers realised that limitations of topography, cultural practise and water supply were affecting the efficiency of their irrigation systems, as well as limiting the yield potential, and leading to runoff and erosion from paddocks.

Background

As is always the case with irrigating in the higher rainfall areas, the rain never falls with the right amount, in the right place at the right time, hence "supplementary" irrigation is required during most growing seasons.

Potatoes have a relatively shallow rooting depth with a higher than usual percentage of roots in the upper section. The practice of planting in highly cultivated raised beds in these soils, although desirable for many sound cultural reasons, has an adverse effect on the water holding capacity of the soil environment in which the plant is to grow.

Tuber initiation occurs about one month after emergence and is complete within two weeks. Water stress at this stage will severely reduce yield by reducing the number of tubers initiated.

The growers felt it was necessary to have a better understanding of the water use characteristics of the crop, where and how much water was being stored in the soil at any given time, and how effectively and efficiently was the water being applied by their irrigation systems if they were to increase their production efficiencies.

Solutions

This project was initiated to:-

A) Assist growers in monitoring the soil moisture levels by the installation of tensiometers and recording of readings obtained.

B) The monitoring of soil moisture levels on an hourly basis over a full growing season using an Enviroscan to allow a better understanding of wetting fronts and crop water use patterns.

C) Assisting the growers in determining the actual application rates that their irrigation systems are delivering, and how effectively it is doing it, while being aware of the effects that elevation change, and operating pressure will have on system performance.

A - Tensiometers

The tensiometer is probably the simplest and most cost effective tool growers can use for monitoring moisture levels in the soil. A tensiometer is an instrument which will give you a measure of how dry the soil is at any given time by measuring the amount of surface tension required to extract the water molecules from the surrounding soil. In simple terms, it is a vacuum gauge connected to a porous ceramic tip via a rigid water filled tube. The tip is in contact with the soil and will try to emulate the moisture condition of the soil in the immediate vicinity of the tip.

How Do They Work?

As the soil dries out, water is drawn from the tube through the tip to the soil. This creates a vacuum in the top of the tube where the gauge is fitted and will be reflected in the reading on the gauge. The drier the soil, the greater the vacuum and the higher the reading on the gauge. When irrigation or rain increases the soil moisture, water is drawn back into the tensiometer, reducing the vacuum and causing a corresponding fall in the gauge reading.

Tensiometers read soil water tension, not moisture content in the soil. This measure of tension is important to the horticulturalist as it gives an indication of how much energy the plant must expend to draw water from the soil.

Placement

As the majority of potatoes are hilled, the placement of tensiometers is slightly different to most other crops. It is extremely hard to site a tensiometer in the hilled area and get reliable readings until the soil has packed down.

For potato crops on the soils normally encountered in the Central Highlands, I would normally recommend two units be installed at each site, a 30cm (1 foot) and a 60cm (2 foot).

Tuber establishment takes place within the hilled area and the majority of the feeder roots are within the 20-50 cm range, therefore this is the area we want to ensure has adequate moisture.

The 30cm unit would be the main monitoring unit and would be used to activate irrigation. The 60cm unit is only there to allow us to know if we are over watering and should <u>not</u> be used as a tool for assessing when the crop needs water.

Installing Tensiometers.

Interpreting Readings

See tensiometer graph (Figure 6)

Because of soil variation between properties, root distribution, plant health and vigour, it is difficult to recommend specific values at which to consider irrigating.

Because we are dealing only with potatoes and these are normally only grown on lighter soils we can come up with some slightly more specific recommendations than if we were talking in general terms about tensiometers.

Previous research has shown that the stomata on potato leaves close and leaf and tuber growth ceases when leaf water potential rises to between 35-50 centibars.

This coupled with overseas experiments lead us to deduce that between 35-50 centibars of soil tension will stop plant growth. These tests were carried out on light sandy soil but can be used as a good guide.

I would suggest that if your irrigation system will allow it, one should think of irrigating when the 30cm tensiometer reaches 30 centibars on light soils through to 40 centibars on medium soils.

After irrigation the 30cm tensiometer should come back to 0-10 centibars within an hour of irrigation and should then rise to 10 centibars within 24 hours. By the same token, if the 60 cm tensiometer comes back to 0 centibars within 24 hours of irrigation, too much water has been applied. Ideally, the 60cm unit should come back to 10-15 centibars within 24 hours of irrigation, but no lower. If the reading on the unit does not drop, too little water has been applied.

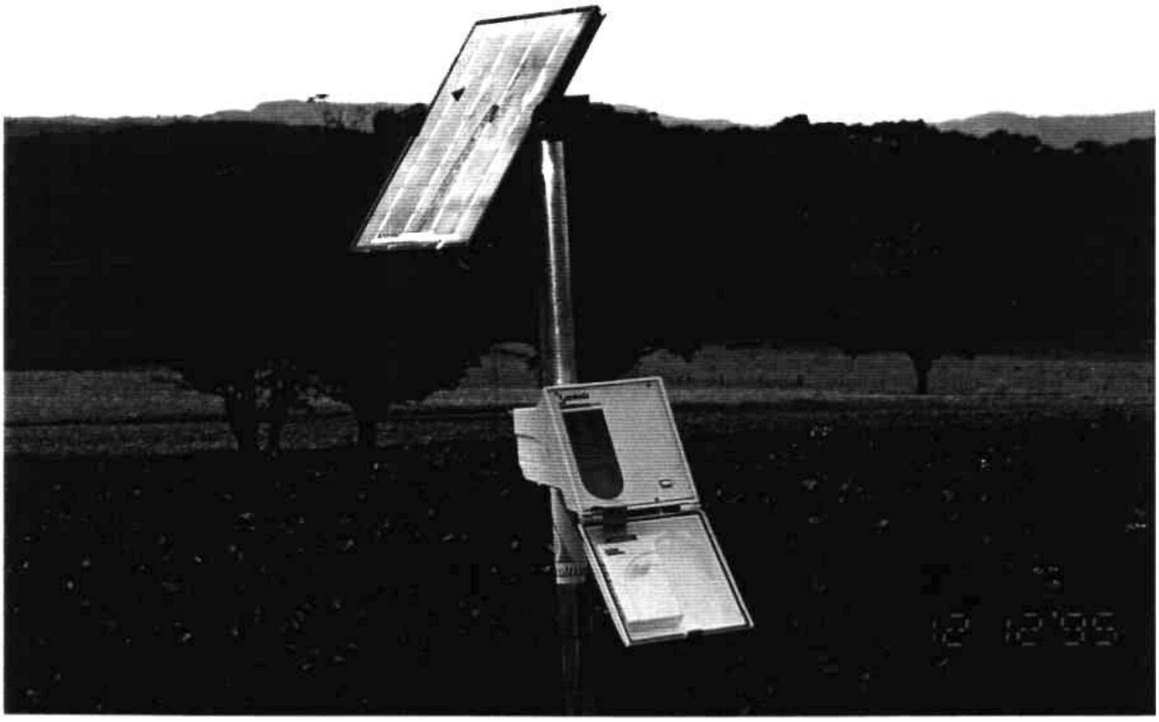
B - Hourly Monitoring of Soil Moisture using an EnviroScan

EnviroScan moisture monitoring probes were installed in two locations within the cropping area, one in the crop row near the travelling irrigator laneway and the second midway between two adjoining laneways, thus allowing monitoring of single pass irrigation application, and overlap irrigation.

The capacitance probe used in the EnviroScan, measures the dielectric constant of the soil, which varies according to the amount of moisture within it. It requires PVC access tubes to be installed within the root zone of the crop and sensors are located in these on a semi- permanent basis. The sensors are then hard wired into a logger at the site.

It is not cheap (between $6000 and $14,000, depending on configuration required) however it does have a logging capacity which means that readings are taken and logged at between 10 minutes and 120 hour intervals automatically. This means that an operator does not have to be on site to take the readings, however, a computer is also required to recover and view data from the machine.

At this stage, the technology is being readily adopted by 'corporate' farms who use them for scheduling irrigations and Government departments who use them for research purposes.



The EnviroScan.

Results of monitoring

As would be expected when trying to undertake an irrigation monitoring trial in a relatively high rainfall area, things did not go completely according to plan, with some 880mm of rainfall recorded at the site during the growing season. For this reason, the crop did not appear to experience any stress due to lack of soil moisture.

Waterlogging is another possible cause of crop stress, and there were two occurrences where the soils was waterlogged for between four and six days, with 230mm being recorded between the 2 - 11/1/96 (See Fig 1). The only reason this did not show up in the final quality of the product was the free draining nature of the soils, the sloping topography and the effect of hilling on drainage.

One of the main tasks undertaken was to measure the effective application rate of the irrigation system and to see if any deep percolation below the root zone had taken place.

Local growers generally irrigate using a fixed speed setting on their irrigators, while varying the length of time between irrigations, giving a fixed application per irrigation. The trial site received a set application rate of 40mm per irrigation.

Monitoring the moisture status in the single pass row showed that the soil moisture increased within the 0 - 50 cm profile by 27mm when an irrigation was undertaken. This was 67 % of the water applied.(See Figure 2)

The overlap area showed an average soil moisture increase of 16mm, being only 40 % of the water applied. (See Figure 3)

Very similar figures were obtained over three separate irrigations with differing antecedent soil moisture conditions, however, this in itself is not the answer, but points to further investigations in the areas of :-

- Actual output and application rates from the irrigator over the full wetted width and throughout the irrigator run length.
- Short and long term infiltration rate characteristics of the soils

The EnviroScan unit was able to give us an indication as to when, and at what depth the crop used moisture, and how quickly water entered and travelled through the soil profile. This showed that early in the growing season, quite large percentages of the irrigations applied were lost below the root zone (See Figures 4 & 5).

One must remember that the 1995/96 growing season was far from ideal for this type of investigation and as such no firm answers could be obtained and recommendations made without further investigation and, hopefully, a drier growing season.

C - Testing Irrigators

By testing our irrigators performance we are trying to determine the amount of water applied per irrigation run and the uniformity of application including the overlap area. A properly designed and operated system, relative to intensity and evenness of water application, will eliminate deep percolation below the root zone and runoff from the field resulting in lower pumping costs and giving greater profits.

The first step is to undertake an application rate uniformity test commonly called a 'catch can test'.

To undertake this test:-

- Place a series of cans in a straight line across the full width of the wetted stripe in front of the irrigator on dry ground. The cans should all be the same size, say 120mm deep by 90mm diameter and must be placed perpendicular with the top edge above the foliage. They should be evenly spaced at between 2 and 3 m depending on the lane width.

- The irrigator should then be allowed to operate from before the spray reaches the cans until the spray pattern has completely passed over the cans. It would be preferable to undertake this test on a day when the wind is lighter than normal. Measurements should be taken of :-
  - a) The travel speed in metres per hour
  - b) The depth of water collected in each can in millimetres
  - c) The pressure at the big gun sprinkler in kilopascals.

- The figures can be plotted on the proforma (See Figure 7). Analysis and interpretation of these results and assistance as to how to improve the efficiency and effectiveness of irrigation systems can be readily obtained from your local NSW Agriculture Irrigation Officers based at Orange, Windsor, Yanco, Forbes, Maitland, Grafton, Wollongbar, Dubbo and Deniliquin.

References & Further Reading

Harris, P.M. (1992) The Potato Crop: The scientific basis for improvement. Chapman & Hall, London.

Marshall D.J. (1987) Development of an Irrigation Scheduling Service for Potatoes. Department of Agriculture and Rural Affairs, Technical Report series No 144

Logan B.J. Crop Water Requirements For Potatoes. Unpublished information sheet NSW Agriculture

Merriam J.L. & Keller J. (1978) Farm Irrigation System Evaluation : A Guide to Management. Utah State University, Utah.

Figure 1

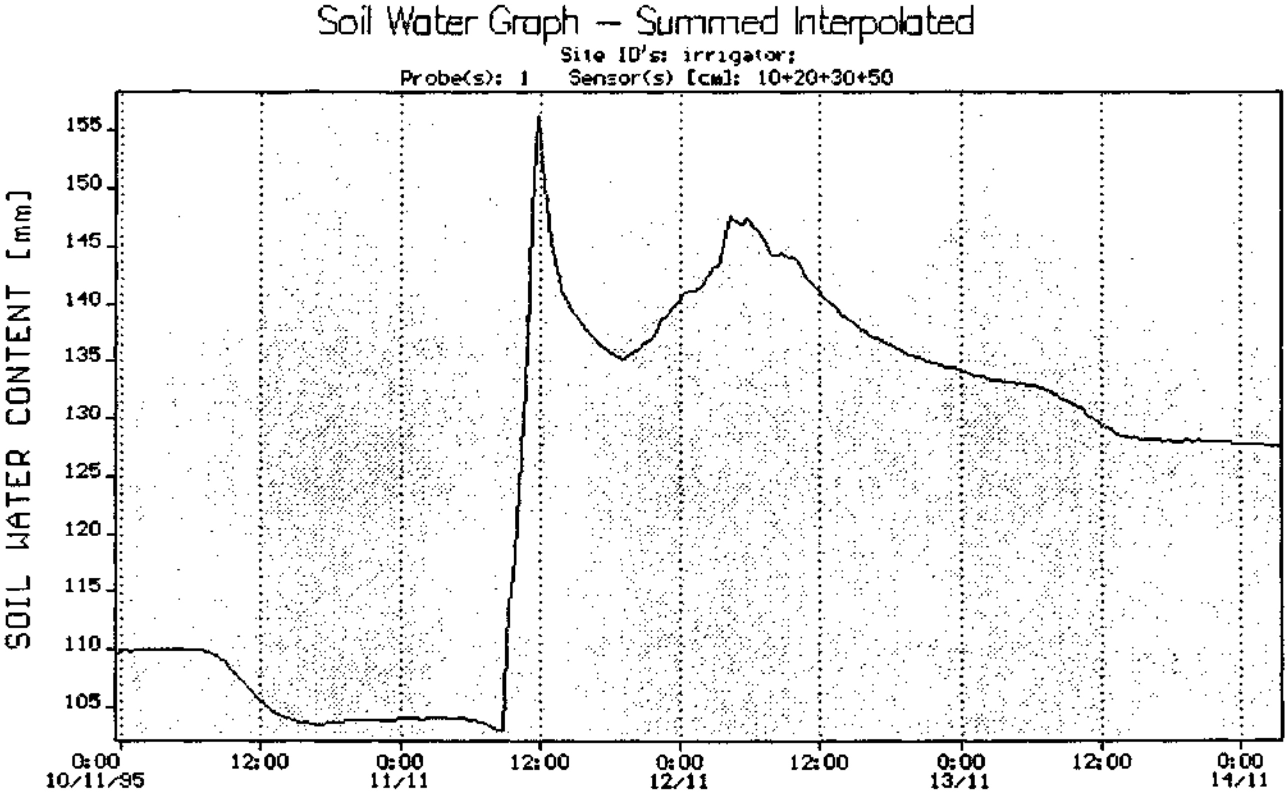


Figure 2

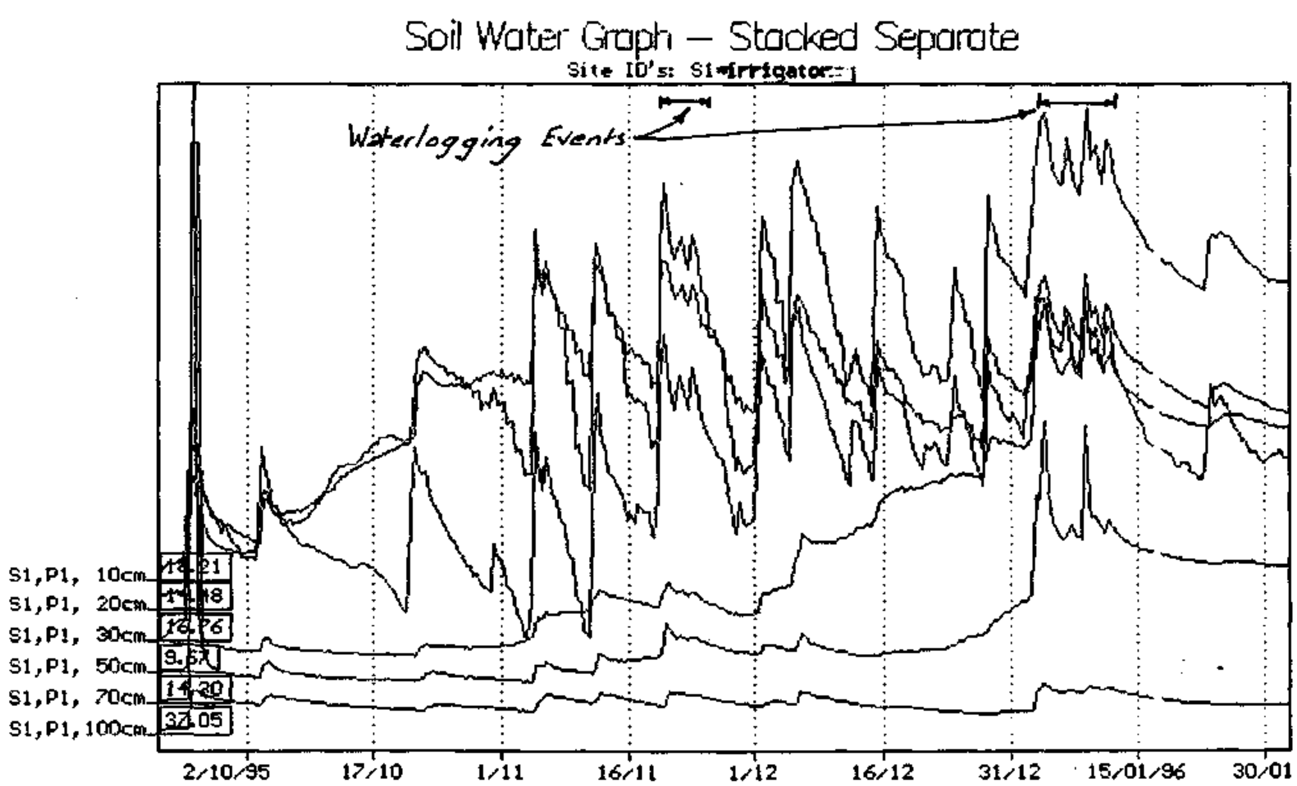


Figure 3

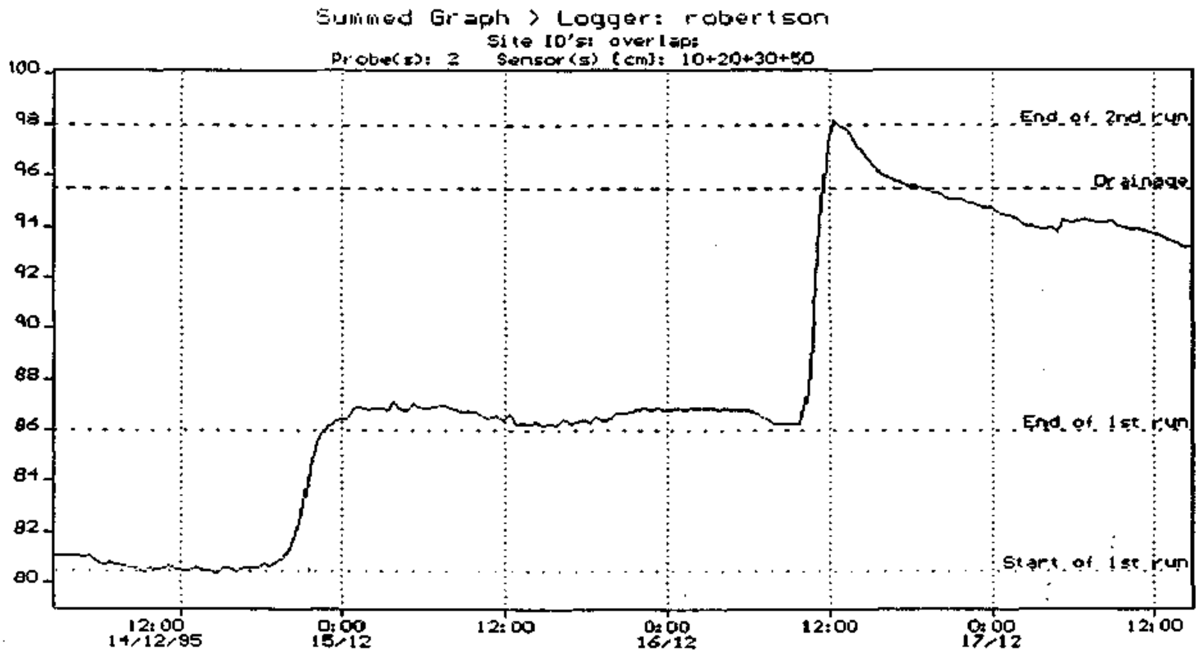


Figure 4

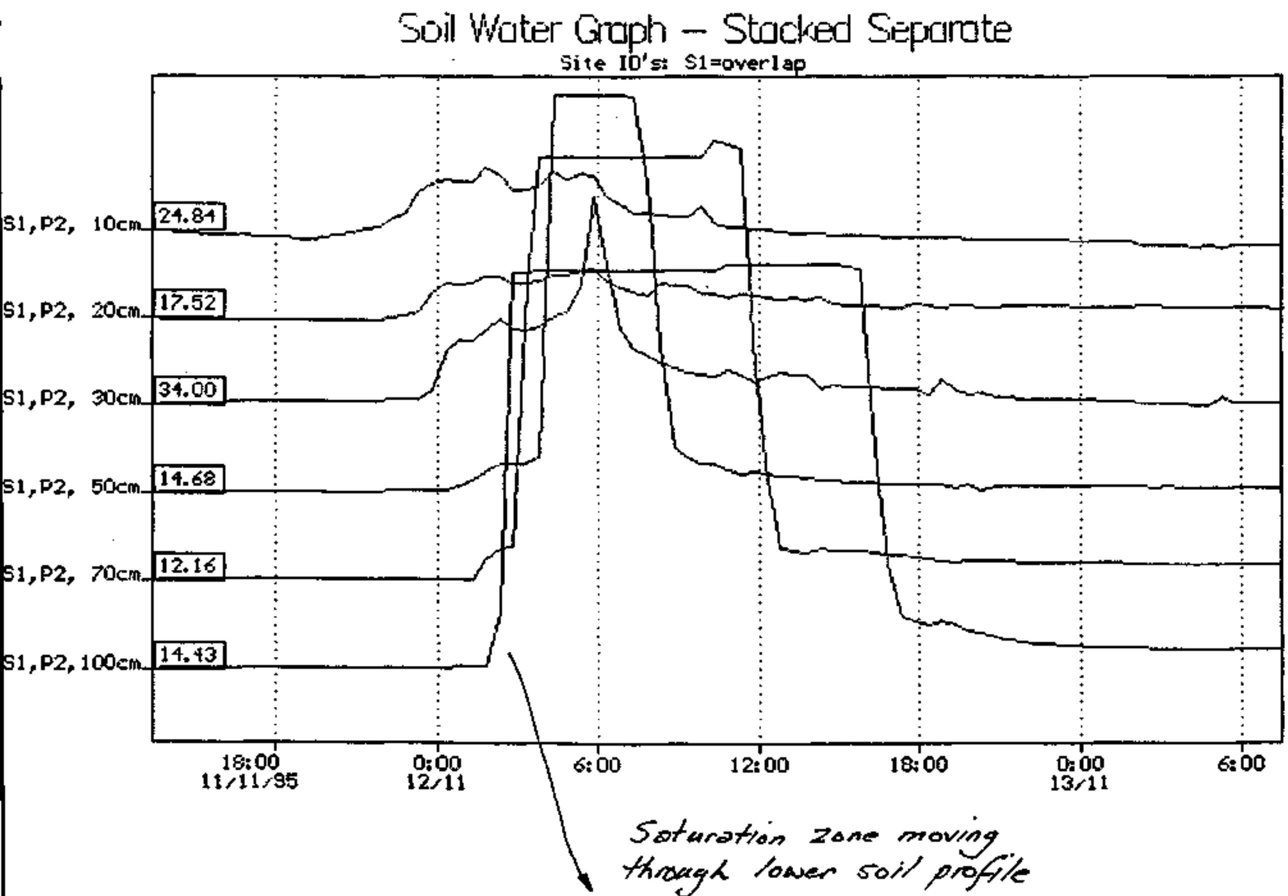
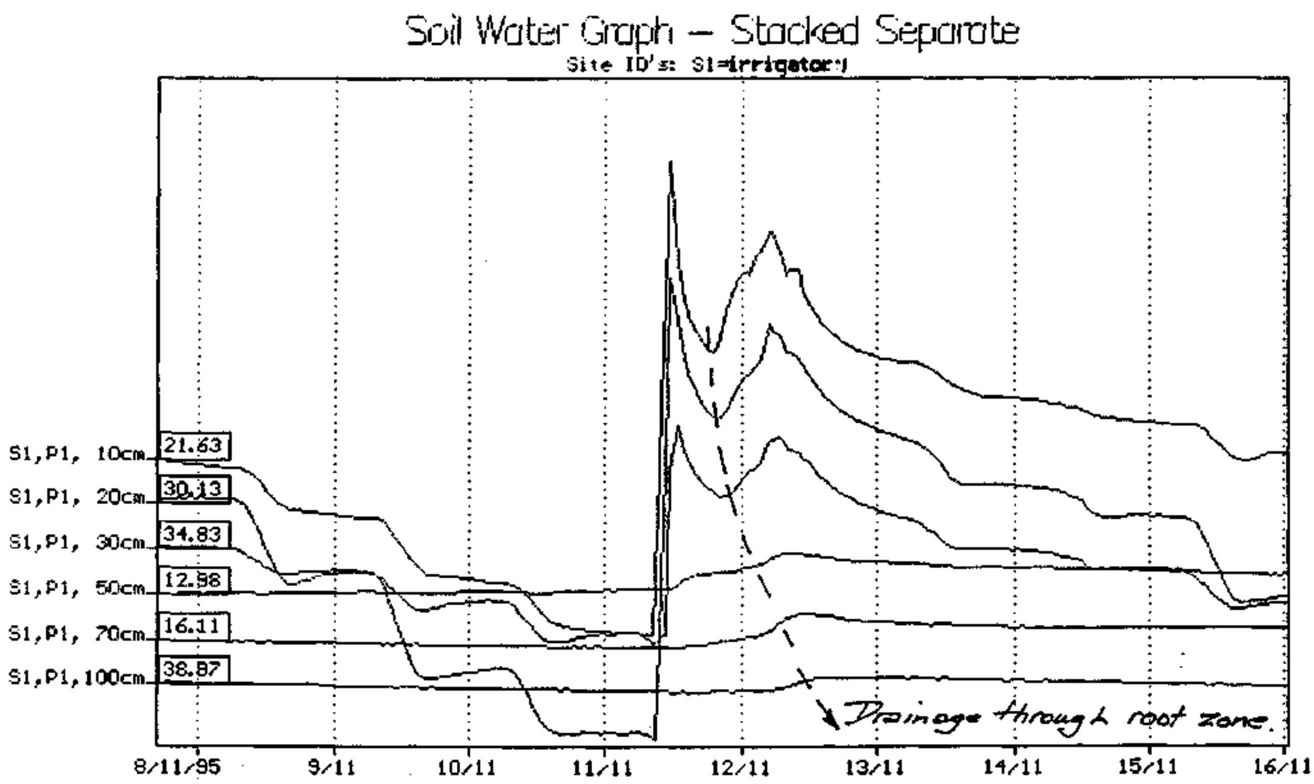
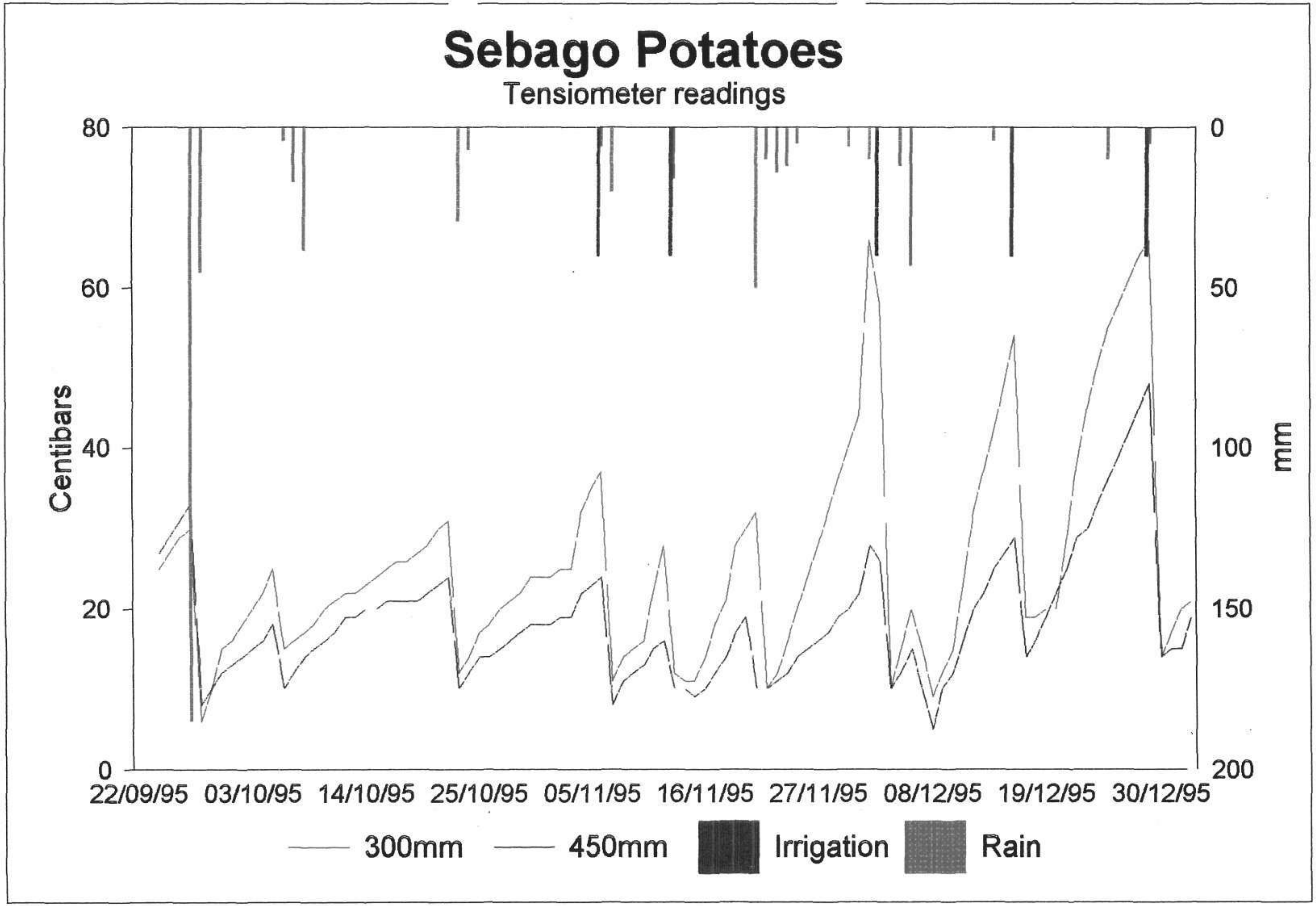


Figure 5


Soil Water Graph – Stacked Separate
Site ID's: S1=irrigator
S1,P1, 10cm 21.63
S1,P1, 20cm 30.13
S1,P1, 30cm 34.83
S1,P1, 50cm 12.98
S1,P1, 70cm 16.11
S1,P1,100cm 38.87
Drainage through root zone.
8/11/95
9/11
10/11
11/11
12/11
13/11
14/11
15/11
16/11


Sebago Potatoes
Tensiometer readings
Centibars
mm
0
20
40
60
80
0
50
100
150
200
22/09/95
03/10/95
14/10/95
25/10/95
05/11/95
16/11/95
27/11/95
08/12/95
19/12/95
30/12/95
300mm
450mm
Irrigation
Rain

NSW Agriculture
IRRIGATION MANAGEMENT SERVICE

SPRAY IRRIGATION - BOOM/LINEAR/PIVOT - DISTRIBUTION PATTERN

NAME............................ADDRESS..

IRRIGATION SYSTEM : BOOM .... LINEAR .... PIVOT ....

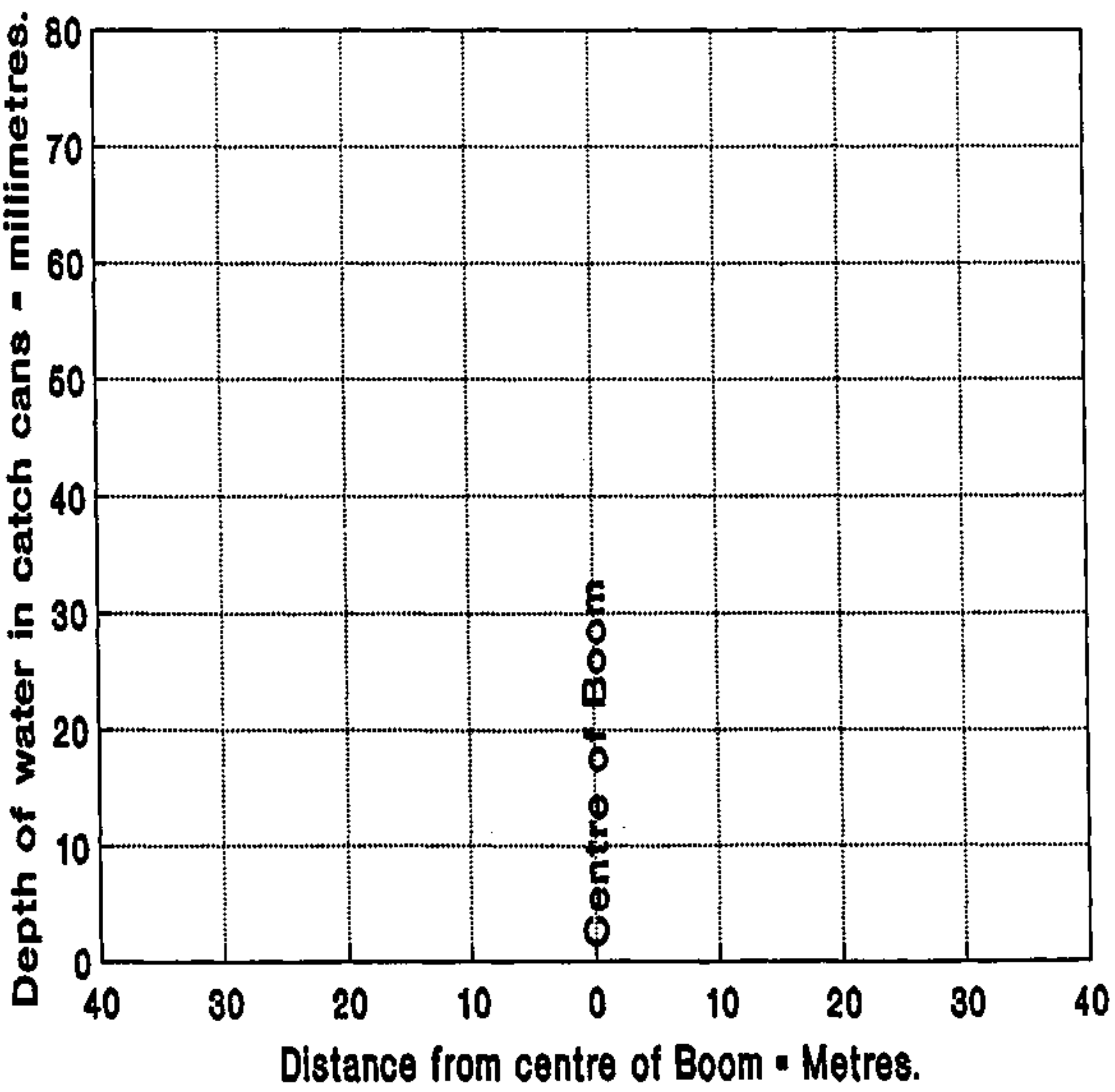
HOW TO MONITOR YOUR SPRAYLINE PERFORMANCE USING CATCH CANS

1. RECORD

Irrigator travel speed	=	....	metres per hour	S
Length of run	=	....	metres	L
Pivot pressure	=	....	kPa	

2. Calculate run time = $\frac{L}{S}$ .... hours H

3. Plot location of catch cans and depth of water collected on the graph below, or use a separate sheet of graph paper to suit.



Integrated Pest Management (IPM) in Potatoes

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Contents:

INTRODUCTION

PRINCIPLES AND PRACTICE OF INTEGRATED PEST MANAGEMENT.

There is no doubt that the high crop yields of quality produce in Australia, and in many parts of the world can be attributed to the use of synthetic pesticides for the control of insect pests, diseases and weeds. Most growers would agree that the easiest way to control a particular pest is to reach for an appropriate, registered pesticide.

There is increasing awareness of the limitations and side effects of a total reliance on chemicals for a quick-fix. Problems include concern for human health and safety, the environmental damage caused by some pesticides, the elevation of organisms to pest status through the elimination of natural or native suppressive agents, and widespread resistance in insects, mites and pathogens (disease-causing organisms) to synthetic pesticides. With a number of crop plants, phytotoxic injury (crop burn) from pesticides is a major problem.

In fact, the rate at which new pesticides are being developed and registered isn't keeping pace with the rate at which others are being withdrawn from the market. As well, increasing legislative controls will further limit the use of those still available.

For two reasons this presents greater risks to potato growers than to other primary producers, namely:

1. The proximity of production areas to encroaching subdivision and urbanisation, and
2. The fresh sale and the snack nature of the processed product.

While some consumers look for organically grown or pesticide-free produce, such products often have major limitations for commercial production, and this concept is therefore unrealistic for a number of crops. Hence, a realistic alternative is to adopt methods which lead to a reduced use (rationalisation) or replacement of pesticides, while still ensuring adequate, profitable yields of quality produce.

The most comprehensive or all-encompassing of these is Integrated Pest Management (IPM). IPM has numerous definitions, but it is essentially about developing and managing systems which combine the use of a range of pest control strategies in a compatible manner, to achieve a more sustainable system of growing and protecting crops. Emphasis is not placed on total pest elimination, but on maintaining pest populations below those causing economic damage. This point is called the Economic or Action Threshold. (Note: a "pest" = insect, mite, disease, or weed).

IPM therefore includes utilising:

- Biological methods [use of predators, parasites and pathogens- (disease causing organisms)]
- Cultural methods (including good hygiene and sanitation, selection of disease resistant or tolerant varieties, modifications to production methods, and design of growing structures)
- Physical and mechanical methods
- Genetic methods (such as resistant varieties)
- Synthetic versions of natural compounds (such as pheromones) and synthetic pesticides, that are used only when necessary, and when their selection is based on causing minimum disruption to other control methods.

The most critical aspect of managing pests is to MONITOR what is going on in the field by scouting crops regularly, preferably every week.

MONITORING: STEP 1

Monitoring is checking what is happening in the field so you have a reasonably good idea of a crop's pest status. This means not only pests and their damage, but beneficial organisms also. It is important to keep accurate records of monitoring, as it also helps evaluation of control measures and for future planning.

The first step is to have an accurate map of the property as well as a field plan, so that data collected can be recorded for decision making, particularly in regard to pest incidence.

Monitoring can be done properly, only if you can accurately identify the common or key pests of potatoes and their typical damage. While many growers can identify pests and their damage, we have found fewer can identify beneficial organisms or non-pest species that are present in a crop (see Table 1).

There are some good publications for identification of pests and beneficials, including publications written by Paul Horne, from the Institute for Horticultural Development, Agriculture Victoria, and The Good Bug Book (1995), by Australasian Biological Control Inc. and available from its members.

The best method of identifying pests and beneficials is from actual specimen collections, such as those developed in several HRDC/APIC funded projects. A number of growers have put together their own pest and beneficial collections which is also useful for training staff.

Monitoring in potatoes is usually best done by visual plant inspection, where randomly selected plants are regularly sampled (ie. a proportion of plants from throughout the crop), and checked for presence of insects, pest damage or disease.

For sampling to provide reliable results, samples should be taken in a pattern that covers the whole crop. This is important as pests may be in patches or on particular sides of the block. Often, symptoms of damage may be observed while walking through the rows, but a more detailed plant inspection can often show small pest numbers or damage which would not have been obvious otherwise, and so provide more warning for implementation of control measures.

Some useful tips for sampling are:-

i) Look at older crops in more detail, as they will give you a guide to future problems in younger crops.
ii) Check the first crops of the season as they will indicate whether there are problems which have lasted during the off-season and which you will therefore need to check this season.
iii) Monitor crops in areas that had a problem in previous seasons. Often, certain locations such as warm or waterlogged positions, or areas previously under pasture show pest damage first.
iv) If weather conditions favour pests, such as warm and dry for many insects, and warm and humid for fungal diseases, monitor more carefully and frequently.
v) Take a hand lens (10x magnification) with you when monitoring. It will enable you to accurately examine tiny sized pests such as thrips and whitefly, as well as diseases. An insect net is also useful for fast flying insects
vi) Use monitoring to see how effective your pest control methods are by monitoring say one week after spraying. This can show up problems with poor application, or pest resistance.

Monitoring by

a) Plant inspection does not have to be a difficult and time-consuming job. It can be done at the same time as the normal operations such as hilling and irrigating. A number of growers train their workers to monitor their crops, and to inform them of any damage or pest build up. Others use professional bug checkers or monitoring scouts.

b) Traps or lures. Pheromones are most commonly sex attractant chemicals that are produced by female moths and other insects to attract males. The chemical composition of many pheromones has been identified, and have been synthesised for use in pest control.

Pheromones can be used for monitoring insect pests, where they are used as attractants to sticky lure traps. Unlike other sticky traps, pheromone lures are very specific in their attractiveness, so are usually only used to monitor one pest species.

In potatoes, pheromone traps have been most commonly used to monitor for potato moth, *Phthorimaea operculella*. There are two types of potato moth traps used in Australia.

The first are commercial delta sticky traps, made of waxed cardboard, with a sticky base. The second type are "home-made" from plastic drums, with large holes cut out of the middle, with the pheromone hanging inside from the lid, and the base filled with water.

In both cases, the synthetic sex lure in a rubber tube dispenser attracts the male moths, which become caught on the sticky bases of the traps, or in the water in the drum base. While the commercial traps are more expensive, it is easier to count moth numbers using them.

Pheromones have also been used in some crops to directly control pests, by bathing the area with pheromone to prevent the males finding the females and mating. This method is commonly called "mating disruption".

Coloured sticky traps also serve a useful purpose in monitoring potato crops for several insect pest species.

Yellow sticky traps can be useful for monitoring aphids (flying stage), planthoppers, whiteflies and thrips. Blue sticky traps are particularly effective for thrips, especially Western Flower Thrips.

Sticky traps are hung in the field just above crop height, and inspected weekly. They should be discarded when they cease to be sticky (after several months) or if more than half the surface is covered in insects or dust. An alternative to sticky traps can be yellow water traps, essentially yellow plastic basins containing water and a drop of detergent to lower the surface tension.

Pheromone & sticky traps are placed in the field & inspected weekly.

Another type of trap is a light trap. True light traps produce light from special wavelengths, such as U/V which are particularly attractive to dusk and night flying species of pests and beneficials. They are especially useful in recording flight and oviposition activity of moth pests such as heliothis *Helicoverpa* spp. and beneficial wasps and lacewings. If a light trap is not available, ordinary fluorescent lights will still give a good indication of night-flying species.

Note: Traps are not a direct means of pest control. They provide growers with management data, to assist in deciding if, and when a spray is needed. Nor should traps take the place of field inspections, they are merely supplements.

Monitoring by visual examination and by traps and lures will indicate when pests are present in crops, and so will assist in timing of control methods. Clearly, there is no need for control methods if no pests are present, or present in extremely low numbers.

THRESHOLD LEVELS

There is a point at which pests reach a level where control measures have to be implemented to prevent economic loss to the crop. This is known as the action threshold or economic threshold, and is based on the pest level in the crop or on pest damage. While pest numbers are not the only factor on which decisions are based, it is never-the-less very important.

In practice, development of field thresholds for pests is difficult, because of differing climatic and crop conditions, differing crop ages, different grower practices, as well as variations in plant varietal response to pests, and market acceptance of damage.

To date, few action thresholds have been developed in Australia for potato crops, and these vary greatly depending on the type of crop (seed, fresh, processing), the district, and the time of year. This is especially important in the case of potential disease vectors such as aphids and plant hoppers in seed crops.

The above comments emphasise the importance of individual growers maintaining good monitoring records, so that they can with time develop their own thresholds, relevant to their location, and management practices.

CULTURAL METHODS: STEP 2

There are some simple cultural strategies which can reduce pests and the adverse impact of their damage. Most of these methods can be described as "crop sanitation" and include:

i) Removal of weeds and volunteer plants from the vicinity of the cropping area. Weeds commonly harbour pests (such as potato moth, aphids, thrips and leafhoppers) and diseases, especially viruses and phytoplasmas that attack potatoes by providing feeding, breeding or hibernation sites. The removal of such plants can significantly reduce or delay the entry of pests into the crop.

ii) Removal of diseased or infested plants (roguing). Plants showing symptoms of virus or other severe disease, contaminate or cross-infect the plants around them. Their quick removal and preferable burning, prevents them acting as a source of infection.

iii) Removal of crop debris. Old crops or plant parts, including "chats" should be destroyed or removed from the vicinity of a growing area as soon as possible after harvest. Such material only acts as a source of pest contaminants for future crops.

iv) Preventing entry of pests into a clean area is a very important part of cultural control. This includes the use of clean seed, and the prevention of soil being carried on equipment, vehicles or by other means.

v) Rotation of cropping areas is an important strategy, especially when soil borne insect pests such as white fringed weevil or soil diseases are encountered.

vi) Surface water such as that in dams may be contaminated with the same pest organisms present in the crop. This is an issue to consider if irrigating from these water sources.

BIOLOGICAL METHODS: STEP 3

There are a range of natural or naturalised enemies of many plant pests. These include predators, that attack and eat their prey, parasites or parasitoids that live for some of their time on live hosts, in many cases eventually killing them, or pathogens (diseases of the pests). At certain times, these natural enemies can greatly reduce pest numbers.

Frequent use of broad-spectrum pesticides can severely reduce populations of beneficials. Such a phenomenon has been recorded in a number of crops actually increasing the pest levels.

It is also possible to introduce beneficial organisms into a crop or district, to establish it there, or to use it as a biological pesticide. While this method has limited use in short-term crops such as potatoes, there are several strategies that have been successfully used against potato pests in Australia.

(a) Potato moth

The most successful of these has been the release of parasitoids against potato moth in particular the species *Cotesia* in Victoria.

(b) Other Caterpillars

A naturally occurring bacterial disease of caterpillars, Bacillus thuringiensis (Bt) has been developed worldwide as a biological insecticide, primarily for caterpillar or grub pests. It is available in Australia under various trade names (Dipel, Thuricide, Biovit etc).

To be effective, the bacterium needs to be ingested or swallowed by the caterpillars/grubs, hence good spray coverage of the crop leaves is essential. Young larvae are more prone or susceptible than are larger caterpillars. "Bt" is only registered for use against a limited range of caterpillars in cucumber crops, eg loopers etc. It has low mammalian (and human) toxicity, and does not interfere with other biological control agents. It is therefore IPM friendly.

PHYSICAL AND MECHANICAL METHODS: STEP 4

These methods can play an important part of IPM strategies for potato production. It is not practical to remove pests from plants, nor to use lure traps for direct pest control. However, the use of both hilling and properly timed irrigation especially in soils that crack when dry are key methods to prevent tuber attack by potato moth.

RESISTANT OR TOLERANT VARIETIES: STEP 5

Most growers will recognise that even with the current commercial varieties of potato, there are differences in susceptibility to pests and diseases. The production of a susceptible variety immediately imposes potentially higher levels of pest control. The breeding of resistant varieties, eg. to phytoplasma diseases, provides growers with options for reduced pesticide applications.

CHEMICAL CONTROL: STEP 6

Chemicals used correctly can provide convenient and effective control of pests. Often, they are the only economical and feasible method of preventing significant product loss. However, incorrect or overuse of chemicals can result in loss of efficacy, problems of human health, environmental hazard and adverse public reaction, particularly to pesticide residues in produce.

Chemicals should be seen as an important part of most IPM programs, and should be selected and applied for maximum benefit. Selection of the most appropriate chemical will depend on its registration status, its efficacy and selectivity against the target pest in the particular crop situation, and its safety to human health and the environment.

Hence, implementing IPM programs requires:

1. Regular (weekly) scouting and monitoring of crops for pests and damage
2. The right selection and correctly timed use of pesticides compatible with natural or naturalised biological control agents
3. Good sanitation practices, including removal and destruction of weed hosts around the production area, as well as plant debris from previous crops.
4. The release of appropriate and effective biological control agents, especially against key pests.

In summary: IPM is an approach to pest control which is becoming more important and more popular with growers, consumers and advisers, as it is the way of the future: to continue to be able to produce good yields of high quality produce with minimum side effects to humans or the environment.

Solutions

A - THE PROJECT: IMPLEMENTATION OF IPM IN NORTHERN AUSTRALIAN POTATO PRODUCTION

This project, which was funded by HRDC and APIC, during 1994, 1995 and 1996, aimed to work with growers in key potato production districts to identify the major pest problems, and grower's approaches to their control.

It also provided monitoring systems with backup identification, to assess levels of pests and beneficial organisms throughout the season. This monitoring information could then be incorporated into strategies to better determine timing of control measures, including the use of pesticides.

The project formed part of a larger national project, addressing issues related to IPM in foliar insect pests. As such, it did not have a mandate to consider diseases, nor tuber or soil-borne insects.

The first stage of the project which was conducted in 1994, was a survey of growers throughout NSW and Queensland. The survey questioned nearly 500 potato growers in these two states on the nature of their production, major potato pests, and their knowledge and interest in IPM.

The general results of this survey were sent to all 105 respondents, and is provided as Table 1. These data are being included in a paper to be published on potato growers' attitudes to IPM in all eastern Australian states.
While potato moth was seen as the most important pest in the Robertson district, which was consistent with most other potato growing districts, growers highlighted

the importance of soil borne insect pests such as white fringed weevil in the Robertson district. This was reflected in the use of Chlorpyriphos by over 60% of respondent growers. The awareness and understanding of IPM by Robertson growers was relatively high (over 50%), but use of IPM strategies was low. Only one grower felt confident in identifying beneficial organisms.

The second stage of the project , conducted in 1994/5 and 1995/6 involved monitoring of potato crops for pests and beneficial species. There were 8 districts in which monitoring took place: one of these was Robertson.

Prior to the commencement of the potato season for monitoring, growers were visited and the aim of the project and the methodology to be used was explained. At that time, the results of the earlier survey were discussed.

Monitoring devices used in all districts were yellow sticky traps , blue sticky traps (2 kinds of both yellow and blue traps, one produced by AgriSense, and available in Australia, the other produced by Rebell, from Europe, and not commercially available in Australia, delta pheromone sticky traps for potato moth (AgriSense) and portable light traps operated by a 12V battery with a light sensor switch (supplied by Entomological Supplies, Bangalow, NSW 2479).

Traps were located in potato crops after hilling, at approx 1-1.5 metres height. Specimens from the sticky traps were sent for counting and identification to University of Western Sydney fortnightly. Light traps were normally only operated one night a week, and again, the specimens collected were sent to UWS,H where they were identified and counted.

Some initial difficulties were encountered with the field rigour of the commercially available sticky traps when used as per the instructions provided with them, especially in hot windy weather. This was overcome by growers tying or nailing the traps to wooden stakes, or star posts. The Rebel traps did not encounter the same problems , but were more difficult to place in the field and collect, because they were not individually wrapped, and so the sticky polybutene contaminated the applicators' hands.

The identification of specimens was divided into three categories: pest, beneficial, and unimportant.

The pests identified were:

i) potato moth - this species can cause leaf and stem mining in potatoes early in the season, and tuber damage later in the season and postharvest. The moth lays its eggs on the undersides of leaves or in groups on tubers. Hatching larvae tunnel into the leaf, feeding just under the epidermal layer at first, but burrowing deeper, into petioles and stems as it grows. The mature larvae emerge from their feeding sites to pupate in a flimsy cocoon on plant debris, or between tubers or on potato bags. The adults are brown-grey moths approx. 10-12mm wingspan. Lifecycle around 4 weeks.

ii) **aphids** - there are two species of aphid commonly associated with potatoes, potato aphid *Macrosiphum euphorbiae,* and the green peach aphid, *Myzus persicae*. Potato aphids are larger, slow moving and pale green. Green peach aphid are green to yellow, but winged forms have dark markings. These transmit potato leaf roll. They were often able to be recognised from the sticky traps because of their colour and morphology, but this was not always possible.

iii) **thrips** - these are small elongate insects around 1-1.5 mm, and commonly brownish. While they directly feed on potatoes, their major damage is the transmission of tomato spotted wilt disease. All thrips on traps in the family *Thripidae* were counted together. This included *Thrips imaginis, T. tabaci,* and *Frankliniella schultzei*, the latter two of which are known disease vectors. The identification to species level, which is time consuming microscopic work is currently being undertaken using the sticky traps from several districts, by NSW Agriculture.

iv) **leafhoppers/planthoppers**- There are two species of planthoppers found on potatoes. These are green (*Austroasca*) and brown (*Orosius*). Both are active flying elongate insects approx 3 mm in length. Both species suck sap from plants, causing marking of leaves, but are more important for their role as disease transmitters. From the traps, planthoppers were recorded on tables as a single score, but the presence of both the green and brown planthopper were separately noted in communication with growers. The brown plant hopper has been implicated with the transmission of "cotton shoot" disease in potatoes.

v) **other moths** - these were primarily from the family *Noctuidae*, and were separately identified as heliothis (*Helicoverpa spp*), loopers (*Chrysodeixis spp*) or armyworms and cutworms (several genera). Heliothis, loopers and armyworms are hairless medium sized caterpillars, of colours varying from green to black and pink that chew holes in leaves. Moths are medium sized, buff or grey with markings on the wings, which fly at night, ovipositing at this time. Cutworms have larvae which feed at night, burrowing into the soil during the day. They attack young plants , chewing them at or near ground level. Their moths are similar to other noctuid species.

vi) **other pests** - found less commonly, but identified included 28-spotted ladybird, Rutherglen bug, wireworm adults (click beetles), African black beetle and other scarabs, wingless grasshopper, and termites.

The beneficials identified were

- **i)** parasitic wasps (small) - an effort was made to identify any of the key potato moth parasitoids, but none were seen in any sample.
- **ii)** parasitic wasps (large)
- **iii)** ladybirds
- **iv)** lacewings
- **v)** hoverflies
- **vi)** predatory beetles
- **vii)** spiders
- **viii)** ants

Information was collated from each sample, and sent back to the grower. The time for reply was up to 2 weeks during the busiest parts of the season. In addition, at the end of each season, data from each district was combined, and a written summary for the season sent out.

Specimens of pests, beneficials, and incidentals identified throughout the project were compiled into a pest collection, which was supplied to the grower(s) participating in the project.

B - MONITORING RESULTS FROM ROBERTSON.

Comparative results are graphed in Figs 1-6

1994/5 season

Monitoring sites were set up at 3 locations in the district, at Tony Strode's, Les Mauger's and Tony Fisk's. First collections commenced in late November, and continued until the end of February. The data indicated an increase in potato moth numbers during the season, with peak numbers in one site (Strode's) in late December, and for the other two sites in mid to late January.

Even at the beginning of the season, moth numbers were moderate, indicating a carryover of moth from the previous season. This is an issue which needs to be considered in future IPM strategies, as there is only a summer crop, so moth is overwintering in the district.

Numbers of moths were comparable with levels seen in other established districts, but lower than some. High numbers of thrips were recorded in December and January and leafhoppers were present in moderate numbers in December and again in February. Aphids were not detected in any worrying numbers during this season.

Regarding beneficial species, there were significant numbers of parasitic wasps except for early in the season, (on one night in December, over 100 in a light trap). The most common wasps were of the genus *Netelia*. These medium sized orange hatchet wasps commonly parasitise caterpillars of heliothis, armyworm and cutworm. In fact, the Robertson district consistently recorded the highest numbers of beneficials of all districts monitored. This may be partly explained by the relatively small holdings, the diversity of flora, and its proximity to remnant rainforest.

1995/6 season
In this season, monitoring was continued at the properties of the 1994/5 participators. The monitoring season commenced in mid-November, and continued until the last week in February. There was a lower level of potato moth activity than the previous season, (maximum100/trap compared with over 200/trap/fortnight in 1995), most likely reflecting the climatic influence on pest populations.

Peak numbers occurred in January and early February. Numbers of aphids were extremely low throughout most of the season, although a flight was recorded in the district in mid-late January. Thrips were consistently present, but not in very high numbers, and planthoppers were present in moderate numbers throughout the season.

There continued to be high numbers of parasitic wasps recorded, but not as high as the previous season. However, larger numbers of lacewings and hover flies (the larvae of which predate on soft bodied insects such as aphids), as well as predatory bugs and predatory thrips were also recorded.

What does this data show?

The data from the two seasons monitoring and the field walk provide a number of important insights into the status of pests and their control in the Robertson district.

1. The differences in insect counts from monitoring at different sites demonstrates that while there was a degree of uniformity in the district, there were also differences in pest and beneficial numbers even in a relatively small district. Therefore, it is important to monitor all crops for pests and damage.

2. In a number of locations, some pest populations increased dramatically in a matter of weeks. This stresses the importance of continuous monitoring, preferably weekly, throughout the season. If particular pests present a problem (eg. aphids in seed crops), monitoring should be more frequent.

3. Potato moth is present throughout the growing season, peaking in mid summer. Even early in the season, numbers were reasonably high. This means that growers need to be on the lookout for foliar mining in the earlier part of the season, and that as tubers form, they are adequately protected from tuber moth by hilling and well-timed irrigation.

   This phenomenon also confirms that potato moth survives from one season to the next in the district, and all alternative breeding sites such as crop debris, volunteer plants and closely related weeds be eliminated via implementation of appropriate cultural controls, to reduce pest pressure for the following season. On the other hand, the presence of potato moth provides conditions more likely to be suitable for establishment of biological control agents such as parasitic wasps.

4. Aphid numbers in the Robertson district are low compared with most other districts. It is difficult to indicate a threshold for winged stages of the green

peach aphid, as it is unclear how many of the population could be active vectors of potato leaf roll. Work related to this project and another with potatoes in Victoria shows variable correlations between vector numbers and disease incidence in the field, consistent with this situation.

5. There are high numbers of beneficial insects, in particular parasitic wasps, compared to other potato districts. These wasps most commonly parasitise caterpillar pests. While the likely reasons for this have been explained above, this phenomenon also supports reduced pesticide applications in potato crops, so that this biological control activity is not suppressed.

6. During both seasons, there was tuber damage in a number of crops by larvae of the whitefringed weevil. This was confirmed by the researcher. Unfortunately, this species was not directly associated with a project on foliar pests. The control of soil borne pests such as weevils, needs to be further evaluated in the eastern states, as well as the interaction of soil applied pesticides on foliar pests and beneficials.

7. With the likely continuing spread of Western Flower Thrips (WFT) from the Sydney Basin, there will need to be increased monitoring for this pest, using yellow or blue sticky traps, located just above the crop canopy. WFT is very resistant to pesticides, and is an important transmitter of tomato spotted wilt virus (TSWV).

8. Overall, it is concluded that future projects on IPM implementation should be in the context of Integrated Crop Management, where all insect pests, diseases, nutrition, irrigation and other practices be considered in a more systemic manner.

Field and grower visits
Visits were made by the principal researcher and other project staff to the Robertson district seven times during the life of the project.

These visits included

- May, 1994: Outline of research program
- September, 1994 Evening grower's meeting; outline of monitoring program.
- Dec., 1994 Field Walk. Presentation of monitoring data, and observation of pests and monitoring.
- June, 1995 IPM Field day
- September, 1995 Grower's meeting
- January, 1996 Grower' meeting
- May, 1996 Grower's meeting and National Chemical Users course.

December 1994, Field Walk, where Robert Spooner- Hart presented the results of the survey and demonstrated pest monitoring techniques.

Outcomes of this project

1. Potato growers in the Robertson district are now able to recognise the common insect pests beneficials in crops, as well as organisms that are neither of these. A specimen collection was presented to the Association, which is, I understand, under the bar of one their favourite "drinking holes"!

2. They are aware of the methods they can use to monitor potato crops, and the importance of constant monitoring and accurately recording data.

3. They better understand the role of all methods, including pesticides in developing IPM programs. This was confirmed by growers achieving high marks in the IPM section of the Chemical user's course (see below).

4. An important outcome of this project was the decision of the members of the Association to undertake the national Farm Chemical User's Course. This course, conducted at Robertson and at a grower's property in May, 1996, by the principal researcher and other accredited University of Western Sydney staff had 9 participants for the 2 day course. All participants successfully completed the course and were accredited. This action, which was publicised in the Good Fruit and Vegetables, encouraged two other potato grower groups in NSW to also express interest in undertaking the course. In July, 1996, a course was run at Orange, and a further one is scheduled in Crookwell in September this year.
5. Further discussions were held between the principal researcher and the Association regarding joint participation in further implementing IPM in the Robertson district, which resulted in two applications being made to HRDC.

CONCLUSION

This project was very well received by the Robertson District Potato Advancement and Landcare Association, and this group was one of the most proactive and interactive in the project's activities. This is in large part a result of the well organised Association, and the work of its Development Officer, Sandra Lanz.

It is expected that a close association between the University of Western Sydney and the Robertson Association will continue, even if further external funding for IPM activities is not granted.

I thank the potato growers who participated in this project, the Association executive and Sandra Lanz, for an interesting and enjoyable time working towards implementation of IPM in potato crops.

TABLE 1

Final Report to Potato Growers. - A survey of major pest problems, chemical usage, knowledge and practices of IPM of potato growers in NSW & Queensland.

Dear Grower,

We have much pleasure in sharing with you the results of the survey, in which you participated.

As you know, the survey tried to find out what the major pest problems were, chemicals used by growers, and grower awareness of IPM (Integrated Pest Management).

We sent out 485 surveys between April and June last year. The area covered ranged from the Riverina, coastal and tablelands areas of southern NSW to north Queensland. Districts included In NSW Guyra, Dorrigo, Robertson, Crookwell, Balldale, Narrandera, Finley, Blayney, Orange, Bathurst and in Queensland Gatton, Ravenshoe, Atherton, and Tolga. We were able to use 105 surveys for data analysis. This meant that our survey was based on a response rate of 22 percent. Growers were grouped according to district name/postcode. The areas sown to potatoes covered in the survey totalled 3,232 hectares (7,986 acres). Of this area, 82 percent was used for fresh table potatoes, 12 percent for processed potatoes and 7 percent for certified seed potatoes. Most (92 percent) was for domestic purposes, with 5 percent being for export. Most of this export was seed potatoes, such as micro-tubers from NSW (Crookwell) or processed potatoes from Qld. Sebago was the most commonly grown variety (90 percent) followed by Pontiac (34 percent), then Atlantic (15 percent) and Kennebec (9 percent). Other varieties, which include Bintji, Crystal etc. together totalled 31 percent of the varieties grown (disproportional percentage).

The potato moth was of the pest of most concern to all growers followed by aphids, then thrips, jassids, white-fringed weevil and African black beetle. Seed growers ranked aphids, thrips and jassids/hoppers more important as pests than did the fresh table or processing growers. This was probably due to viruses they transmit (Tomato Spotted Wilt, Purple Top and Leaf-roll virus). Caterpillars and the African black beetle were ranked next in importance by seed growers, whereas both the fresh table and processing growers ranked the white-fringed weevil next.

The use of pesticides was thought of "very important" and the main control method by 65 percent of growers. Only a small number of growers (12 percent) stated that pesticides were unimportant. The main chemical used was methamidophos (Monitor(, Prefect(, and Nitofol() (66 percent of growers). The next most used chemical was chlorpyrifos (Lorsban() (42 percent) followed by endosulfan (Thiodan() (41 percent). The main application method used was boom spray equipment (90 percent). Aerial spraying was used by 44 percent. Only 7 percent (disproportional percentage) used pellet/dust application.

Most growers (91 percent) were interested in reducing pesticide use mainly because of cost, although some growers mentioned safety and environmental issues as reasons for wanting to reduce usage. It was pleasing to find that 60 percent of growers have heard of IPM. Of this 60 percent ,less than half (42 percent) , however, thought they had a good understanding of IPM. Only 10 percent replied that they had "no understanding" of IPM. Industry associations were the most important source of grower awareness of IPM (41 percent) (disproportional percentage). The next most important source was the Department of Agriculture (32 percent). It was interesting to note that almost one third (30 percent) of growers heard of IPM from other growers. Trade journals were also important sources of information.. However, the most important professional source for growers were the contractors and consultants, (combined 46 percent) when grouped together.

While it was pleasing to find that 60 percent of growers had heard of IPM, only 15% indicated that they used IPM. However, of these, most (97%) said that IPM was important to them. Potato moth and aphids were the target pests of most IPM practices. Amongst those growers who had heard of IPM, there was a reasonable level of understanding of IPM practices. While respondents considered that non-calendar spray/low spray play an important role in IPM they ranked this lower than other strategies. It is possible therefore that growers may not have a complete understanding of IPM. Almost all growers (99 percent) monitored their crops, with 22 percent using a specific device for monitoring (such as pheromone traps, light traps, sticky traps). Pheromone traps were the most commonly used device (11 percent). Potato moths were the major target of monitoring programs (86 percent), with aphids next (65 percent), followed by thrips (45 percent).

Fewer than half of the growers believed that they had beneficial insects in their crops (44 percent), with over half believing that they have no beneficials in their crop or being unsure of their presence (52 percent). However, grower ability to recognise such organisms may be a major factor in this view. Seventy-six percent of growers believed that they could identify insect pests. However, 56 percent believed they could not identify beneficial insects. Only about one fifth of those surveyed (22 percent) believed they could readily identify beneficials. Examples of beneficials given by growers in crops included bees, spiders, ladybirds, lacewings, wasps and worms. An interesting result from the survey was that those growers who have recently adopted IPM appear to be the most proficient in their understanding of IPM.

What do the above results tell us?

1. Pesticides are still the most widely used control strategy by growers, with certified seed growers being most heavily dependent on chemicals. However, because of the dynamics of potato pests, many growers, especially fresh table and processing growers, have employed a low frequency spray strategy to combat pest problems. Unfortunately, the broad spectrum chemicals most commonly used can be disruptive to development of IPM systems, since natural predators and parasites are reduced or eradicated .

2. Potatoes are a crop which are suited to an IPM approach and it was pleasing to find that 15 percent of all potato growers are attempting to implement IPM. One of the major benefits is that this should delay the onset of pesticide resistance in insects which is characteristic in a number of other cropping systems.

3. IPM is still not well understood. Apart from plant inspections, specific monitoring strategies, such as using pheromone traps, light traps and sticky traps could be more widely used to more accurately assess presence of pest and beneficial species.. Monitoring is a critical phase in an IPM strategy. Some common misconceptions about IPM are: 1. It involves the use of no chemical pesticides. 2. It involves the use of only biological control agents. 3. It is expensive, complicated, time consuming and often doesn't work. The adoption of IPM for potato growing, as for many other crops, has been relatively slow.. More work is still required to teach and promote the theory and practise of the IPM approach to pest management.

4. Almost all growers are interested in alternatives to chemical spraying and are interested in learning more about IPM.

Please note:

a) "disproportional percentage" means that growers could tick all choices and this led to overlap between categories and thus did not equal the number of respondents in the survey;
b) socio-economic problems were not part of this survey;
c) pests such as nematodes, bacterial & fungal pathogens were not part of this survey.

What is IPM?

In IPM, emphasis is placed not on pest elimination, but on the maintenance of populations at levels below those causing economic damage. IPM seeks to integrate appropriate chemical spray programs with other methods of control. Monitoring pests and their damage, as well as beneficials via field sampling, and the use of trapping devices such as pheromones and sticky coloured traps, are important features of an IPM program. Cultural management practices include hilling and irrigation to maintain a soil barrier between the tubers and the moth and removing self-sown potato plants, diseased plants (roguing) and weeds, can prevent the build-up of insect pests early in the season. Properly timed irrigation can prevent soil cracking and thus protect tubers. Better timing and selection of insecticide applications can result in satisfactory pest control with less pesticide. Naturally occurring or introduced biological control agents such as bacteria, nematodes, fungi, insect predators and parasites can assist in maintaining pests at low levels. These approaches are combined with other techniques such as plant breeding for pest resistance. Host plant resistance studies have also emphasised the need for an IPM approach to pest management.

What will happen next?

We are interested in following up this survey by visiting and talking to growers. As the potato is the principal vegetable crop grown in Australia, it is important that disease and insect pests are controlled in an effective, yet environmentally sound manner. There is considerable community concern about chemical residues in food crops. For all of the above reasons, Integrated Pest Management (IPM), offers the best strategy for potato growers but IPM can be a difficult concept to understand. This apparent complexity of IPM could be a reason for poor rates of adoption of IPM by growers.

We believe we have now obtained a clearer picture of current practices in insect pest control in NSW and Queensland. This has given us a firm baseline for decision-making. We believe that the results of this survey demonstrate a need to devise further strategies to meet the need of potato growers for a better understanding of IPM. Hopefully, with this clearer understanding, a greater adoption of IPM will follow. We aim to monitor progress in the adoption of IPM as well as the success or otherwise of further stages in the research project such as workshops & consultancies to increase growers' knowledge and use of IPM. We thank you for your participation in this research project, look forward to working with you in the future and welcome any comments from you.

Yours sincerely,

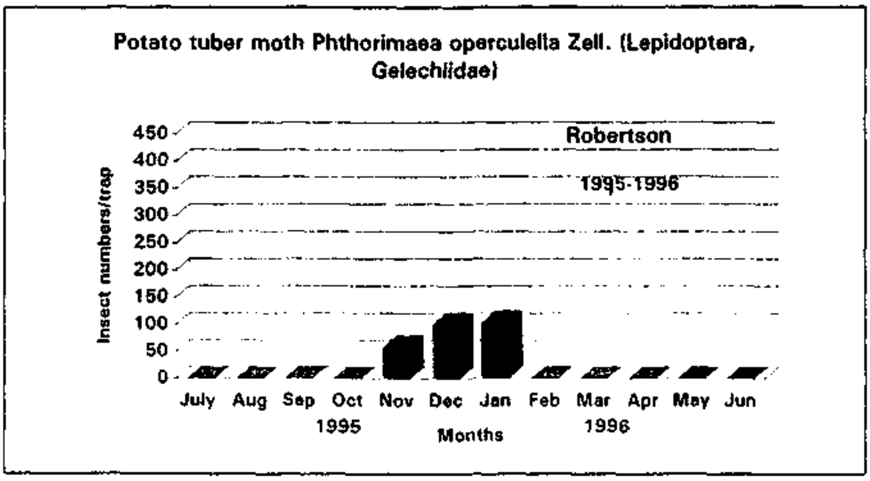
R.Spooner-Hart.
Principal Researcher.

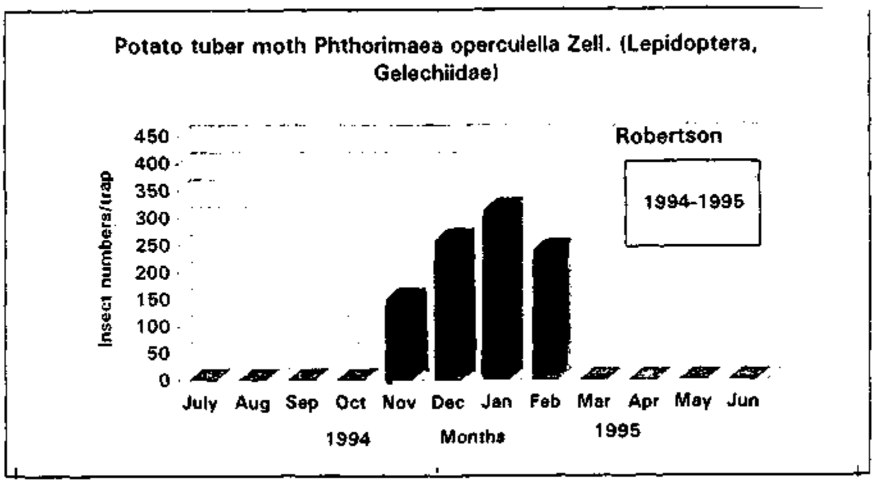
H.L.H.Redgrove.
Research Assistant.

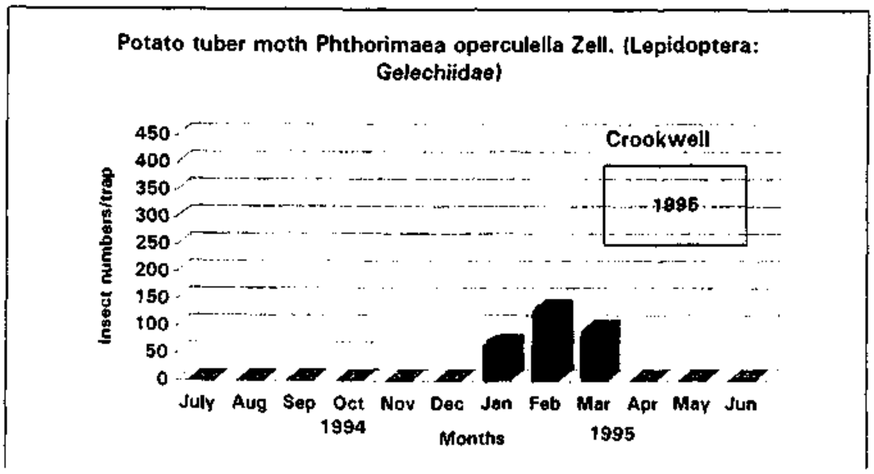
University of Western Sydney, Hawkesbury, School of Horticulture, Richmond, NSW 2753.
Australia. March, 1995

This research was funded by APIC and HRDC whose assistance is gratefully acknowledged.

Figure 1 : Potato moth counts in NSW districts.







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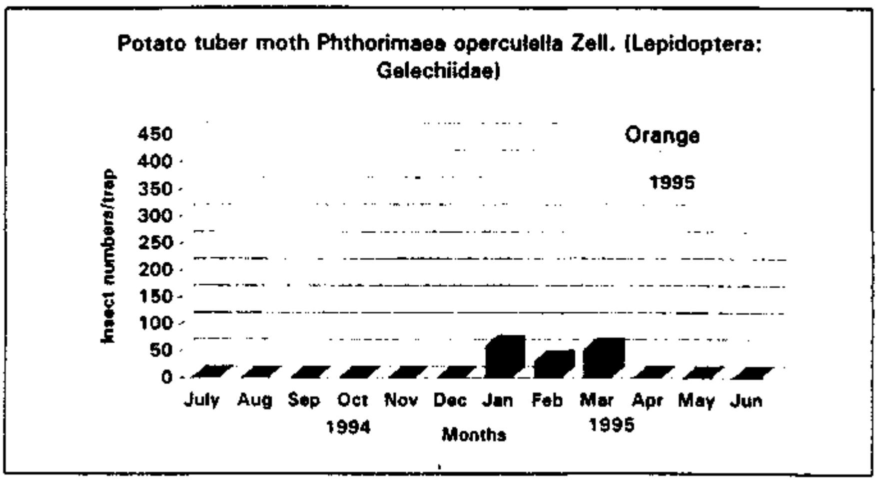


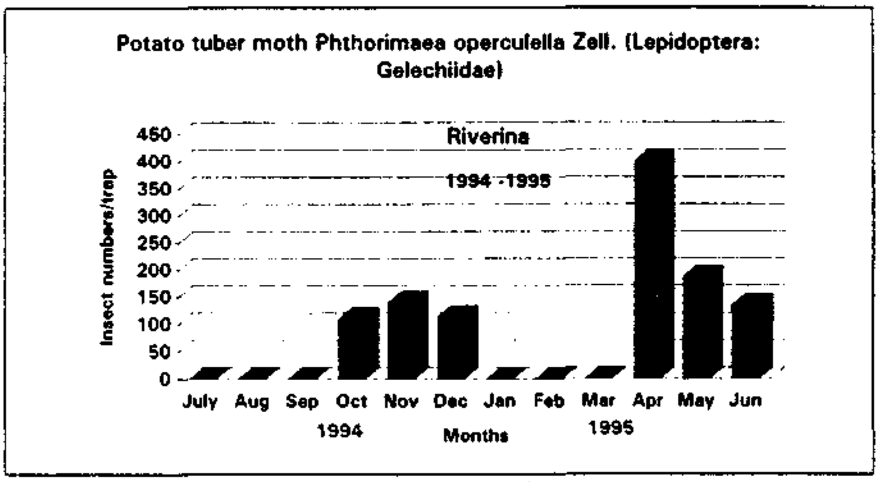
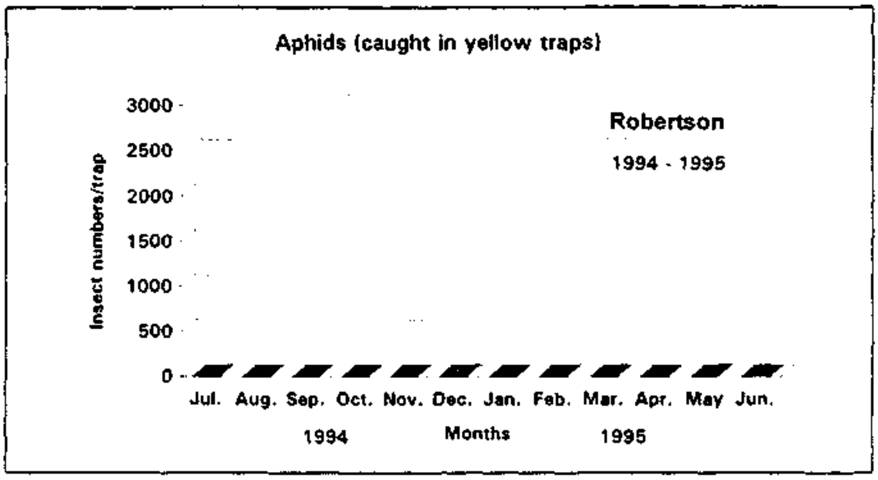
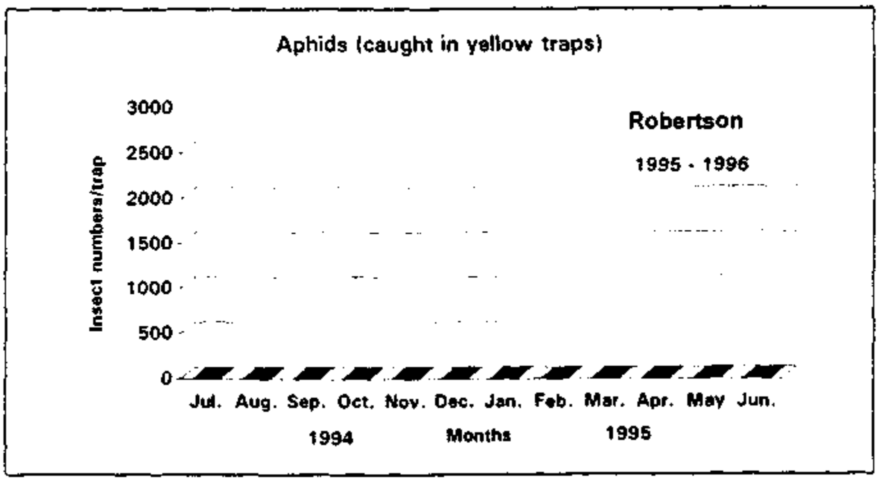
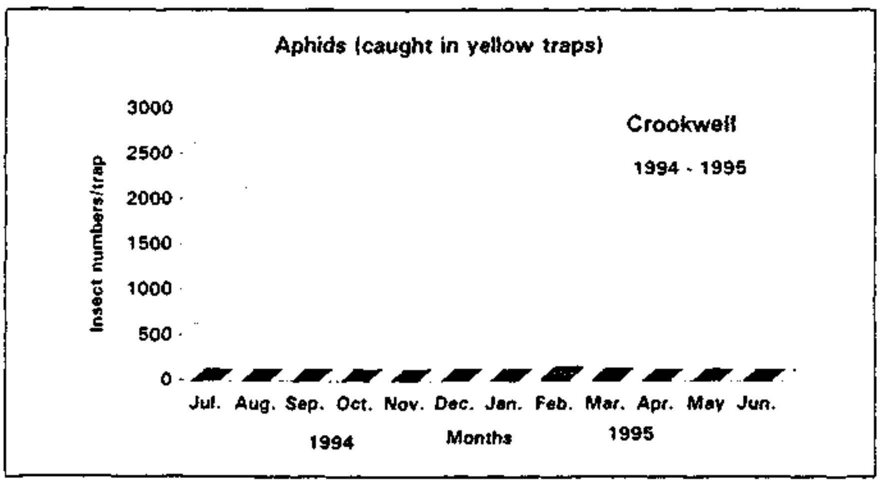


Figure 2 : Aphid counts in NSW districts.







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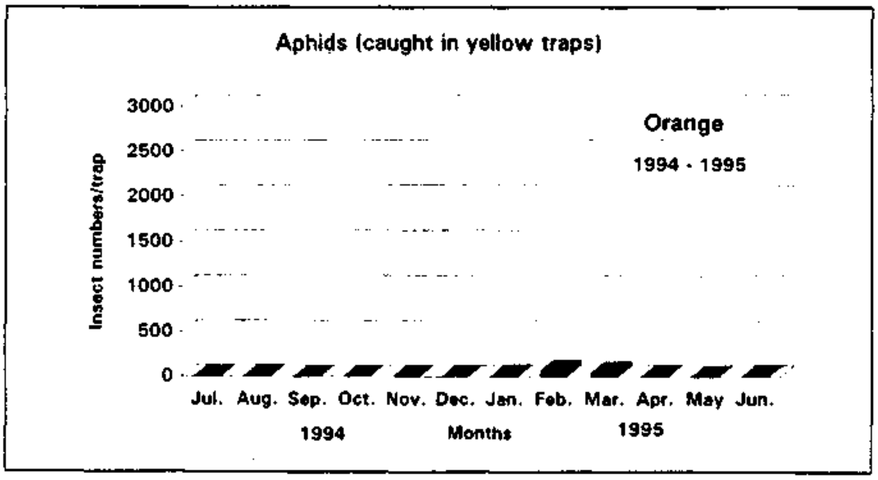


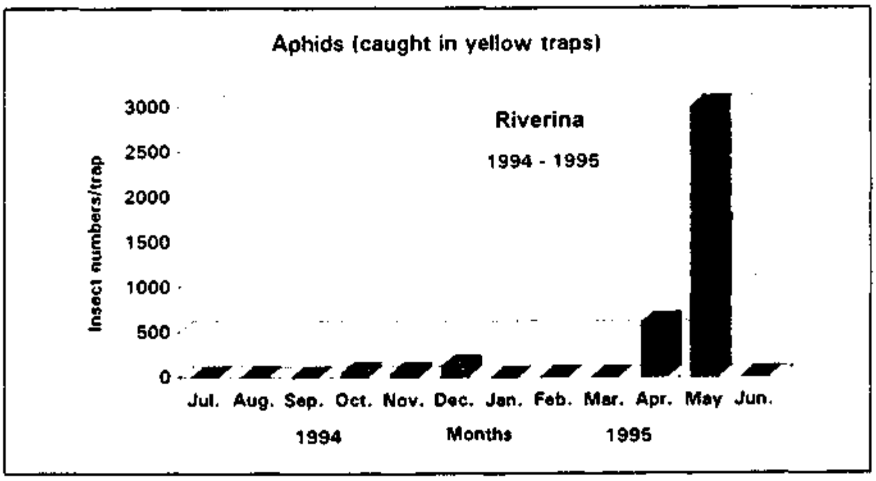
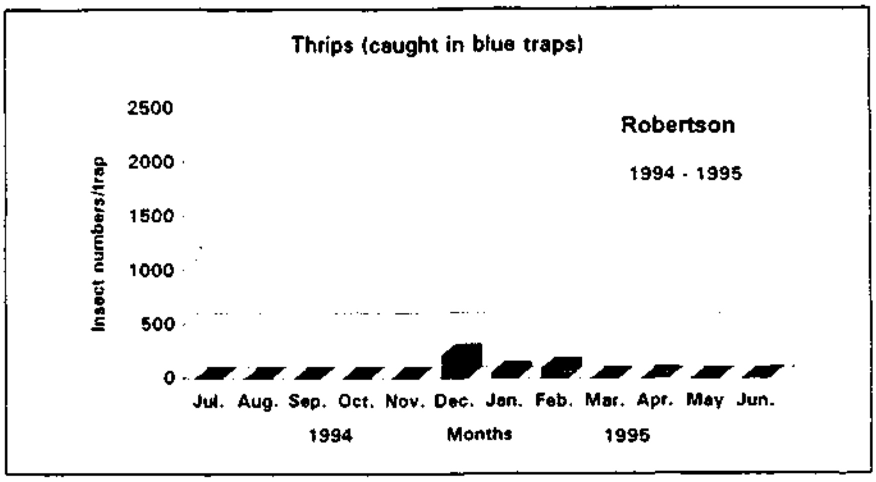
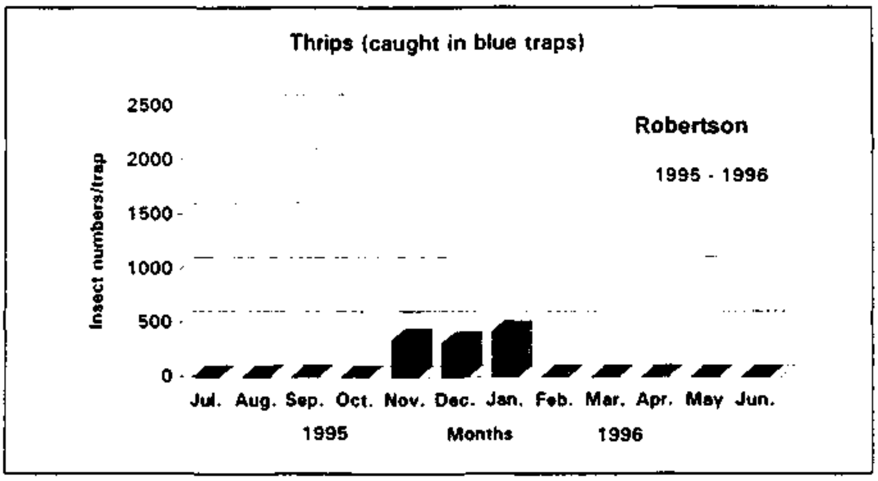
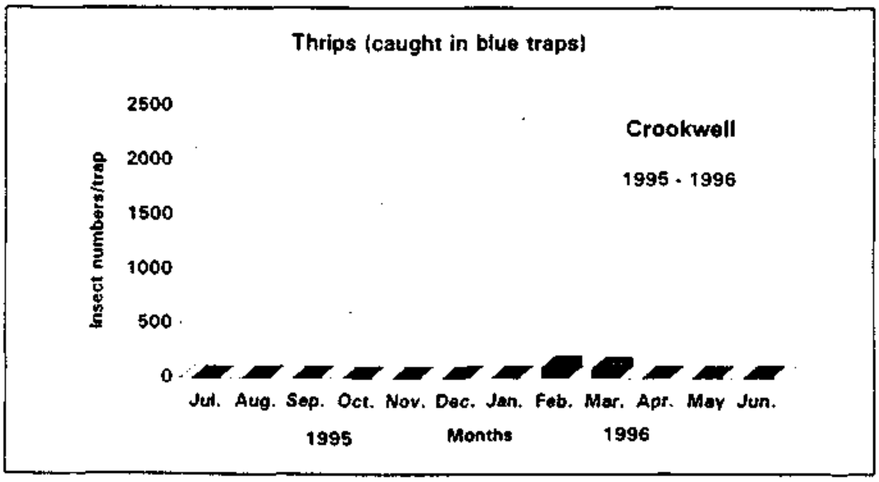


Figure 3 : Thrip counts in NSW districts.







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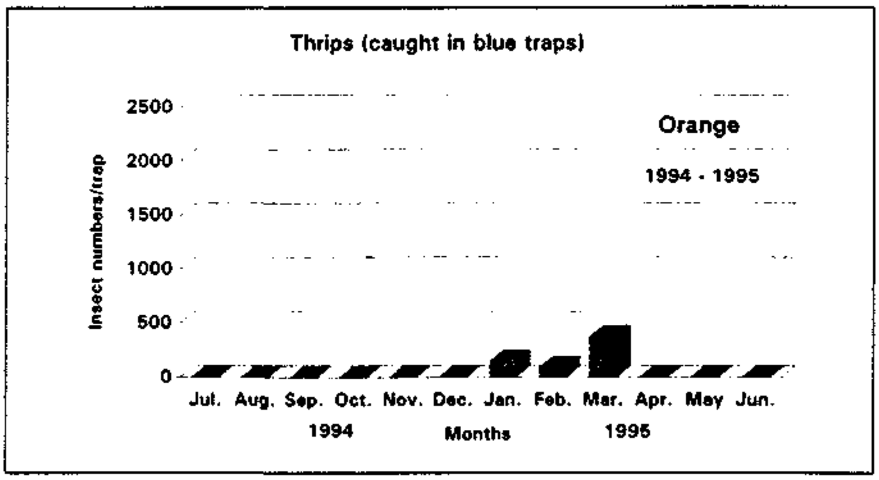


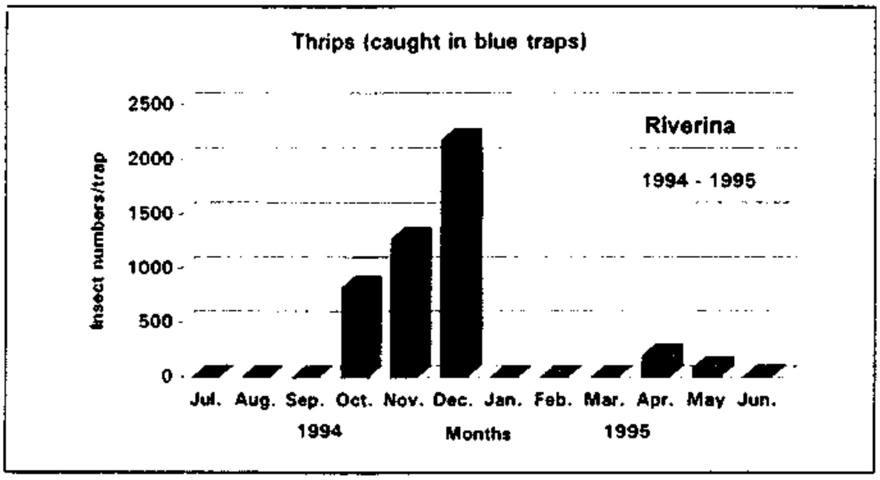
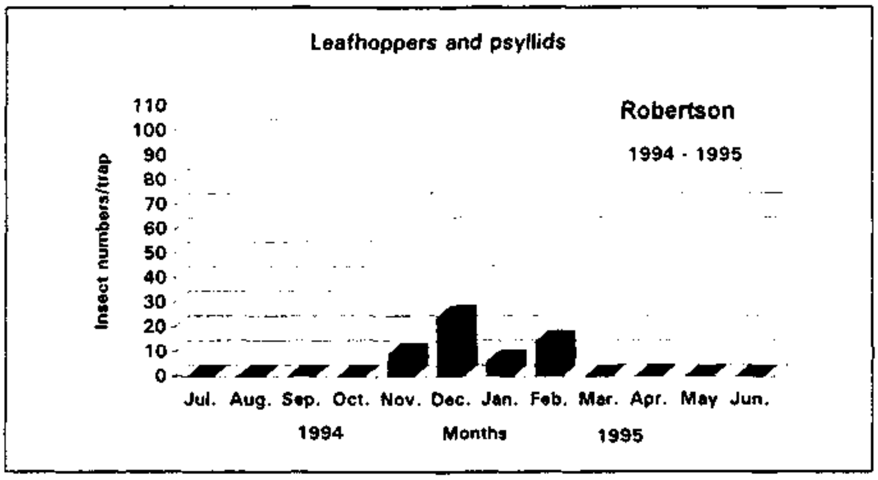
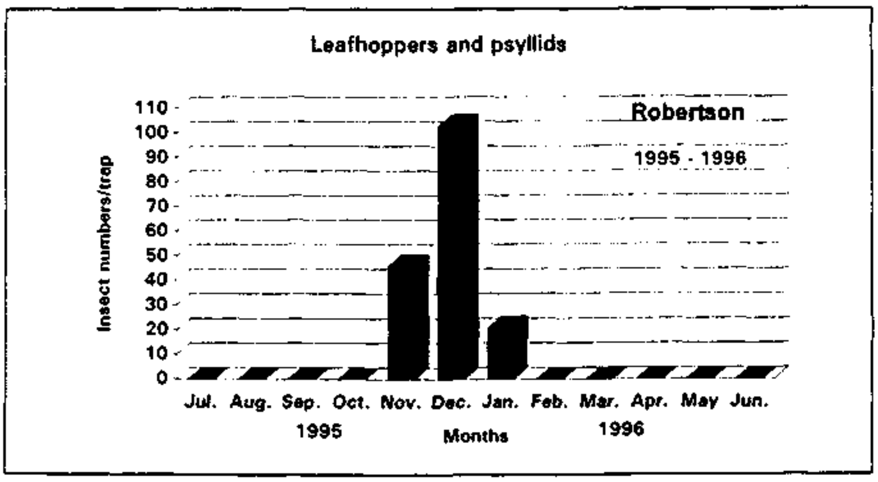
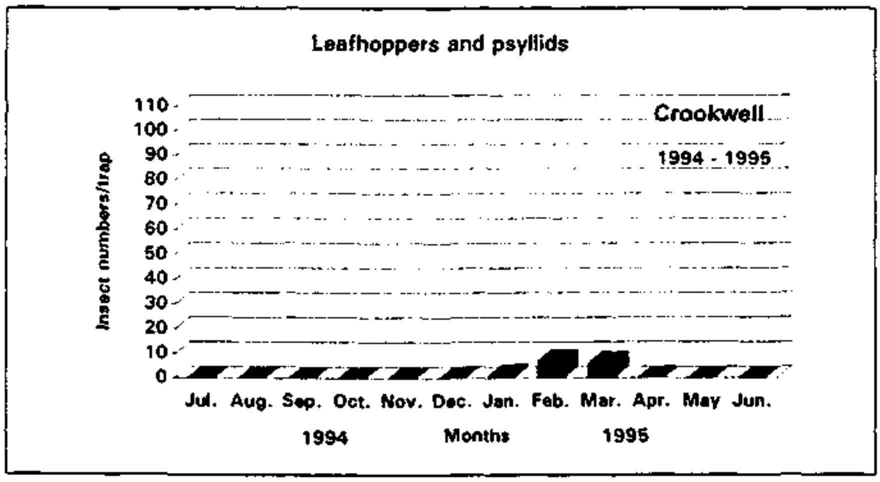


Figure 4 : Planthopper counts in NSW districts.







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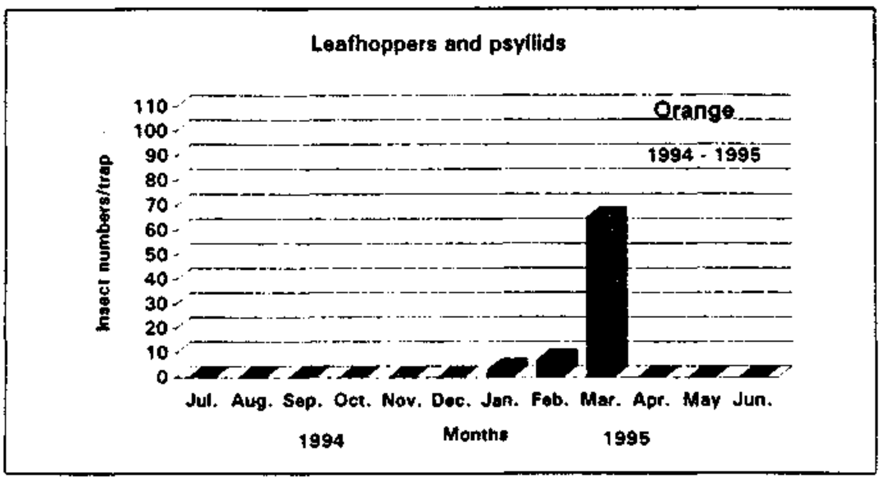


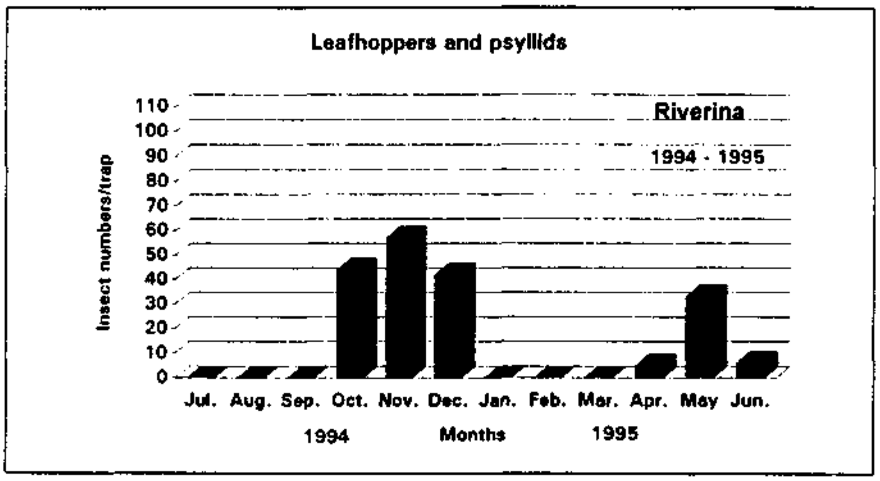
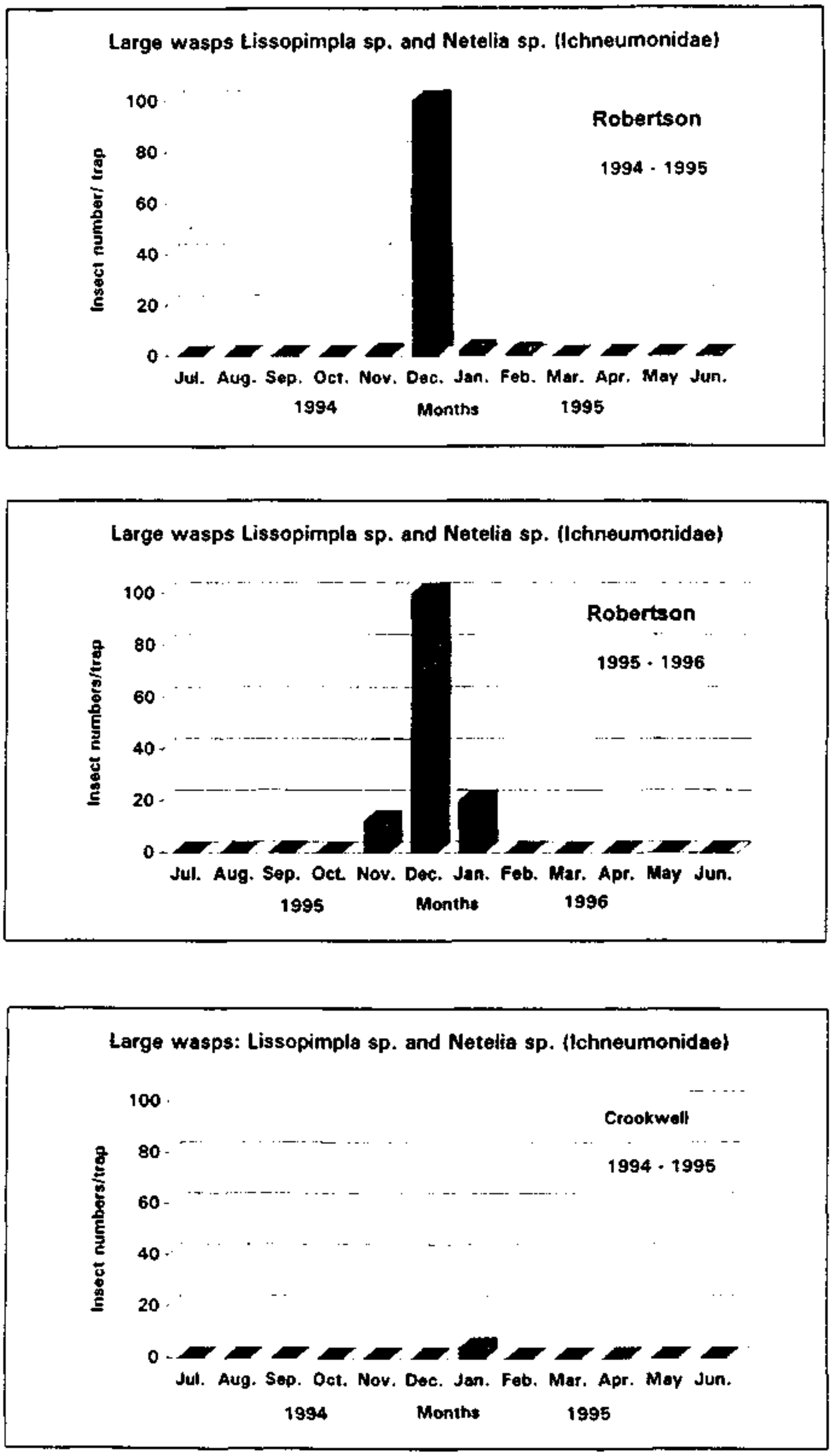


Figure 5 : Large wasp counts in NSW districts.



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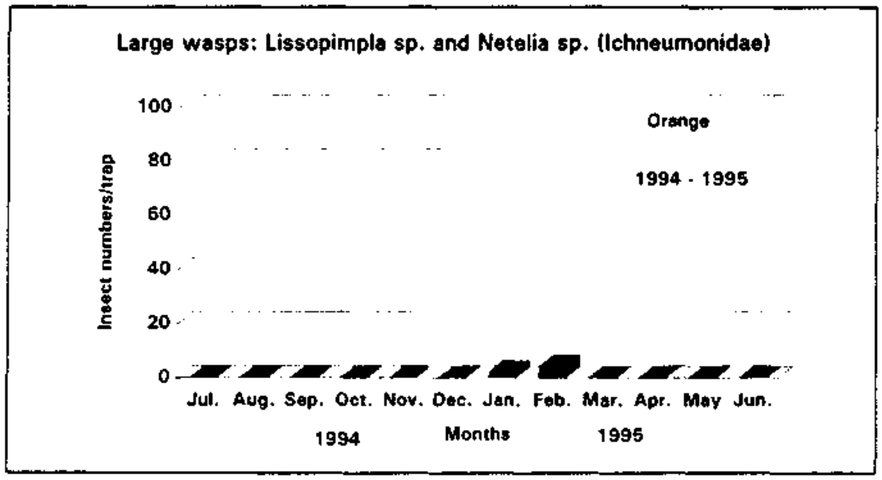


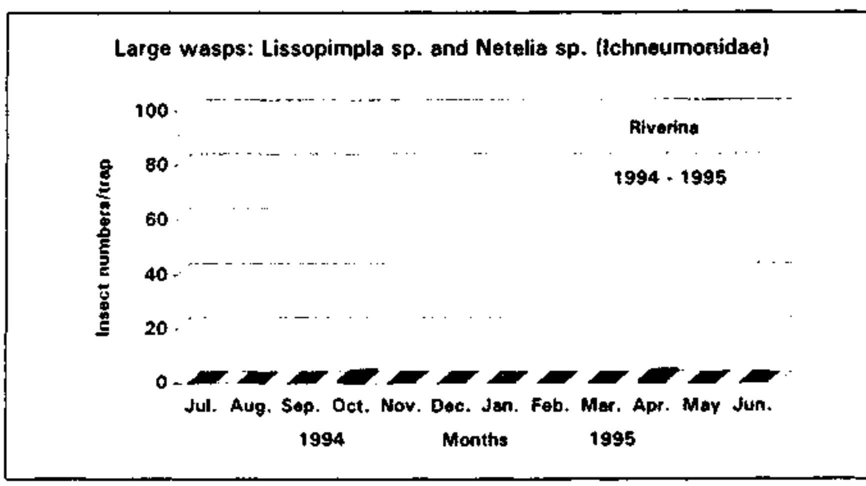
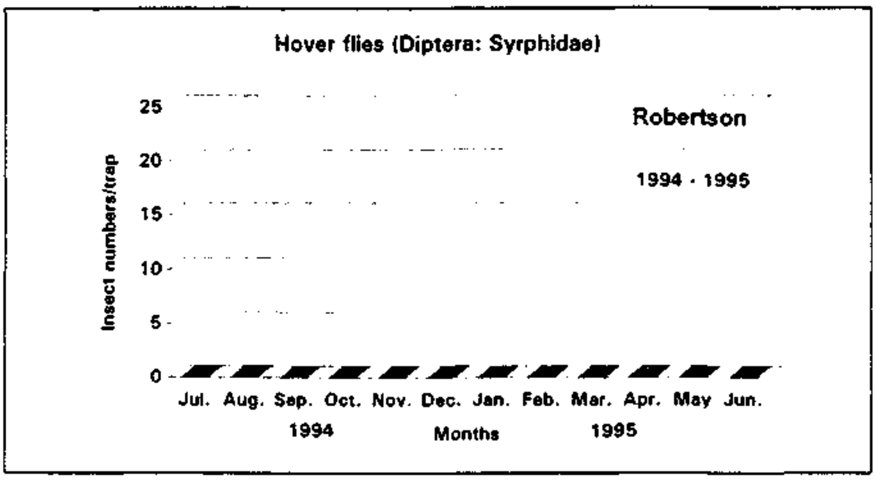
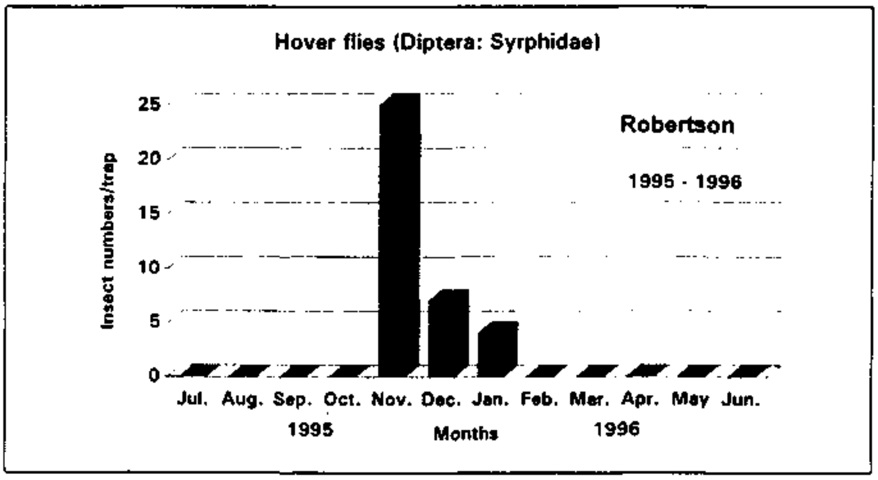
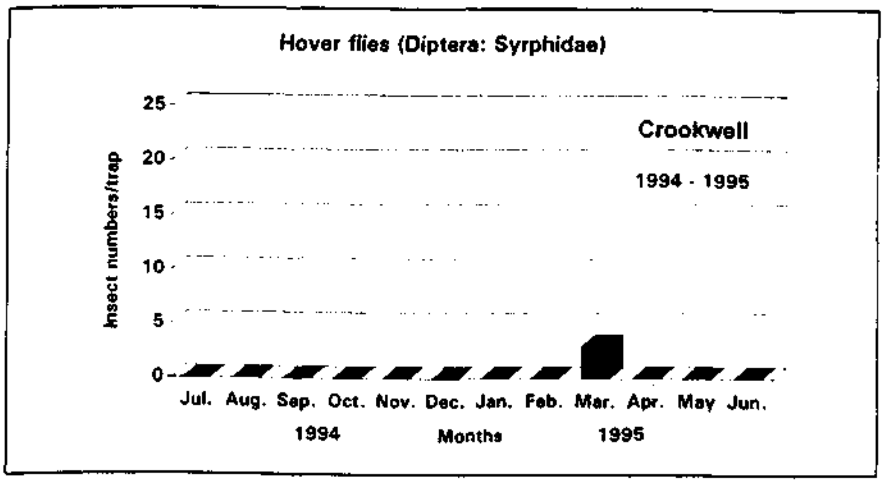


Figure 6 : Hoverfly counts in NSW districts.







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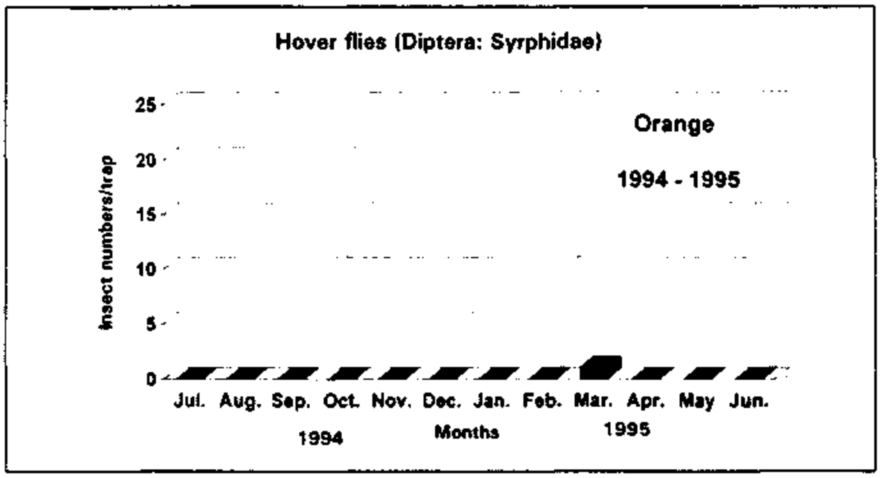

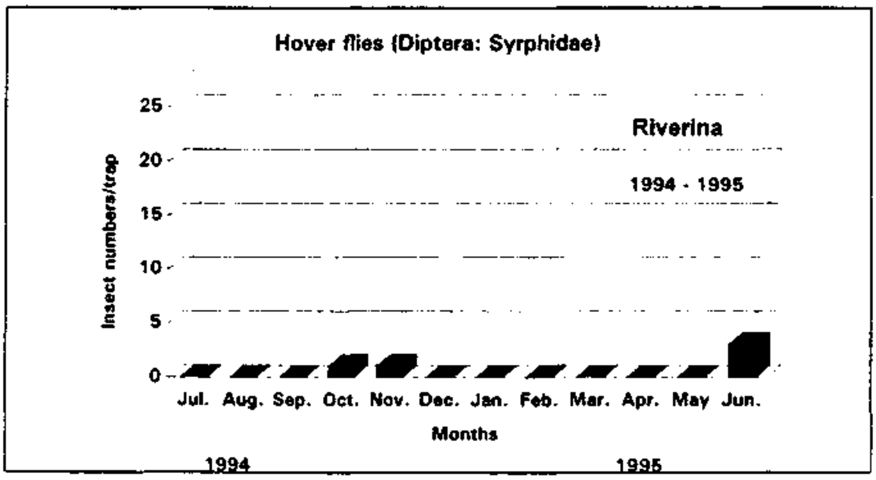

APPENDICES

PT337

Discussion Forums:

	Date	Speaker	Topic
1	10 Nov, 1994	Sandra Lanz	MEY Check
2	8 Dec, 1994	General	Discussion re: Project Manual
3	21 Dec, 1994	Robert Spooner-Hart	Insect ID Field Walk
4	9 Feb, 1995	Mike Robbins	Irrigation
5	16 March, 1995	Graham Liney	Salad Potatoes
6	6 April, 1995	Len Tesoriero	Potato Diseases
7	8 June, 1995	Ben Dowling	Technitubers & Variety Evaluation
8	13 July, 1995	David Carter	Seed potatoes - from lab to field
9	10 Aug, 1995	Graeme Ratford	Sydney Markets
10	21 Sept, 1995	Mike Robbins	Installation of tensiometers
11	19 Oct, 1995	Sandra Lanz & Snow Donovan	Slide show and discussion regarding the Atherton visit
12	9 Nov, 1995	Phil Herd	The Process of strategic planning
13	11 Jan, 1996	Tony Hartley	New Product for Target Spot Control
14	15 Feb, 1996	Mike Robbins	Enviroscan & Tensiometer Results.
15	9 May, 1996	Sandra Lanz	Variety Evaluation - Trial results
16	13 June, 1996	Garth Hutchinson	Phosphorus management strategies for krasnozem soils in Robertson.
17	11 July, 1996	Brian Gaffney	Disease Forecasting
18	8 Aug, 1996	Dolf de Boer	Powdery Scab

Field days:

- May 6, 1994 - To view seed, fertiliser and tillage trials.
- May 12, 1995 - To view results of Fertiliser demonstration plantings and soil amendment applications.
- April 12, 1996 - To dig fertiliser demonstration plots for 1995/96.

Seminar Days:

August 28, 1994 - Speakers:	Roden Mauger - P. G. of A meeting report Tony Fisk - National Conference report Sandra Lanz - Crop Monitoring Sandra Lanz - Comparative analysis Guy van Owen & Kath Chalmers - Minimum Till trials
September 1, 1995 - Speakers:	Sandra Lanz - Crop Monitoring results & discussion Guy van Owen - Minimum Till trials Robert Spooner-Hart - IPM

Media articles:

- Minimum Till cuts soil loss at Robertson. The Land Southern Edition November 25 1993.
- Production study begins. The Land, November 25 1993
- Robertson potato growers on the road to greater productivity. Southern Highland News, August 17, 1994
- Sustainable ways gain ground at Robertson. The Land, September 8, 1994
- Improvement in potato production figures. Town and Country Magazine. Sept 12 1994
- On the road to greater sustainability and productivity for Robertson Potato Growers. Potato Australia Vol 5 Nov 1994.
- Spud program., Power Farming., Vol 105, No 1, 1995 p15
- Workshop on the humble spud. Highlands Post, April 26, 1995
- What is happening to our humble spud. Southern Highlands News, April 26 1995
- Robertson Growers Accredited. Town and Country Magazine, Dec 4 1995
- Crop to yield nutritional secrets for spud growers. Southern Highlands News May 1, 1995
- Sustainable Potato Production in Highland Australia. Potato Australia, Vol 6, 1996.