Know-how for Horticulture™

Monitoring and developing management strategies for soil insect pests of potatoes

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Department of Agriculture
Western Australia

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- **Statement about the purpose of the report:**

Consumers' demands for blemish free potatoes place Australian potato producers under considerable pressure to minimise damage by soil insects. By their nature, soil pests are difficult to detect. This project aimed to provide growers with information to define risk of damage from the major pests and to clarify the situation in relation to soil pests of lesser importance. Control strategies were reviewed and assessed also. This information was to be collated as a management manual for potato growers and/or consultants to provide confidence in defining the risk of damage and implement appropriate control strategies.

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Media Summary

Consumer demand for blemish free potatoes place Australian potato producers under pressure to minimise damage by soil insects. This damage occurs as a result of control measures being inadequate or growers taking no action when, unbeknown to them, pests are present. Seed potato growers also need to produce potatoes with minimal damage and certainly without the presence of soil insect pests, to avoid spreading them to uninfested areas; for example to growers whose farms are free of whitefringed weevil, a non-flying insect.

By their nature, soil insects are difficult to detect. This is because soil is a difficult medium to sample and growers may not always correctly identify soil insect pests. The soil pests are of particular concern where growers use leased land and therefore do not know its history. Routine use of insecticides is likely, whether they are required or not, unless monitoring is shown to be reliable. This project sought to improve the ability of growers or their crop consultants to determine whether crops faced a risk of damage by soil insects and if required, implement appropriate management strategies to minimise or eliminate the risk.

At the start of the project, the team of collaborators defined the main soil insect pests of potatoes in Australia and the states in which they were important as 1. whitefringed weevil (Western Australia (WA), New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA) and Tasmania (TAS)), 2. African black beetle (WA and NSW), 3. potato wireworm (VIC), 4. whitegrubs (QLD, VIC) and 5. rice root aphid (QLD). Mole crickets and black field crickets were mentioned by potato growers in south east Queensland as pests and therefore need to be considered in any potato pest management program in this region.

Monitoring guidelines for assessing abundance of whitefringed weevil, African black beetle and potato wireworm to define risk of damage have been developed. Such guidelines are required for other pests and in some cases their pest status and control methods require clarification also.

In conjunction with assessing monitoring methods, demonstrations of current insecticides and trials to assess new insecticides, in general, clarified the most effective products for the main pests. A recommendation for extension of the chlorpyrifos label to include redheaded pasture cockchafer is being made.

The information from this project will be used to produce a Soil Insect Pest Management Manual for Australian Potato Growers. The Manual will have application for all regions of Australia including those in which the project was not undertaken. The Manual is intended as an aid for growers or crop consultants to define the risk of damage by soil insect pests prior to planting potatoes and describe appropriate pest management strategies.

Technical Summary

This project was put forward to develop management guidelines for Australian potato growers to help them reduce damage by soil insect pests. Reducing the abundance of soil pests had the added advantage for seed potato growers of minimising the risk of spread of pests to uninfested areas, such as the flightless pest whitefringed weevil.

By their nature, soil insects are difficult to detect. This is because soil is a difficult medium to sample and growers may not always correctly identify soil insects. The soil pests are of particular concern where growers use leased land and therefore do not know its history. Routine use of insecticides is likely, whether they are required or not, unless monitoring is shown to be reliable.

We sought to assist growers or crop consultants they employ to reduce the pest status of soil insects by developing and confirming monitoring guidelines for the major pests. We also attempted to identify what pests were important in regions where soil pest damage had been reported but the causal agent not identified.

At the start of the project, the team of collaborators defined the main soil insect pests of potatoes in Australia and the states in which they were important as 1. whitefringed weevil (Western Australia (WA), New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA) and Tasmania (TAS)), 2. African black beetle (WA and NSW), 3. potato wireworm (VIC), 4. whitegrubs (QLD, VIC) and 5. rice root aphid (QLD). At the conclusion of the project, the list expanded to include whitegrubs in NSW and crickets and wireworm in QLD.

Following is a summary of the main management aspects for the major soil insect pests:

Whitefringed weevil:

> Far North QLD (FNQ) - pest status depended on area in Atherton Tableland where crops are grown; pest managed with crop rotation; insecticides provided good pest control.
>
> NSW - generally a minor pest but pest status requires clarification in the Robertson area; pre-crop monitoring in infested areas such as Dorrigo and Guyra to confirm its presence would allow some production without insecticide treatment.
>
> VIC - pre crop soil sampling provided good guide as to risk; insecticides gave good control.
>
> WA - in most cases pre crop soil sampling provides good guide as to risk; insecticides give good control, but some exceptions.

African black beetle:

> NSW - can be a major pest in both Dorrigo and Guyra districts; pre-crop sampling is important to define risk of damage and use of light traps for invasions may help.
>
> WA - pest status and unnecessary insecticide use reduced by pre-crop monitoring; light trap grid provided a good warning service to protect crops from invasive flights.

Cockchafers (white grubs of beetles):

> FNQ - one species identified but more work required to clarify insect identification and their importance. Increasing areas under sugar cane could result in greater abundance of cockchafers.
>
> NSW - in the Dorrigo and Robertson areas one species at least was recorded in very high densities in pasture. Identification and pest status of this pest group require clarification.
>
> VIC - red-headed pasture cockchafer identified as a pest, but the identification and pest status of other possible species require clarification; use of a rotary hoe did not

result in a sufficiently high larval mortality to protect potatoes in one heavily infested paddock.

Wireworms:

FNQ, South East QLD and NSW - identification and pest status of species present require clarification; whether in-furrow application of insecticide is sufficient to control the pest requires assessment.

VIC - baiting was used successfully to assess risk of damage; soil incorporated insecticide gave good control.

Rice root aphid:

Minor pest during this study; crop rotation heavily implicated with its prevalence in the past; a fungus disease was isolated from some infested areas.

Other pests:

South East QLD - mole cricket and black field cricket in south east Queensland were reported as pests; pre-plant monitoring methods need to be assessed.

WA - although considered to be minor pests, apple weevil and garden weevil need to be considered in any cop protection program.

In conjunction with assessing monitoring methods, demonstrations of current insecticides and trials to assess two new insecticides clarified the most effective products for the main pests. A recommendation for extension of the chlorpyrifos label to include redheaded pasture cockchafer is being made.

Monitoring guidelines for assessing abundance of whitefringed weevil, African black beetle and potato wireworm to define risk of damage have been developed. Such guidelines are required for other pests and in some cases, their pest status and control methods require clarification also.

The information from this project will be used to produce a Soil Insect Pest Management Manual for Australian Potato Growers. The Manual will have application for all regions of Australia, not just the regions in which the project was undertaken. The aim of the Manual is that it be used as an aid for growers or crop consultants to define the risk of damage by soil insect pests prior to planting potatoes, and to direct them to consider appropriate management strategies. To cater for this, existing services could be expanded and new monitoring services for soil insect pests of potatoes may be initiated.

Introduction

Consumers' demands for blemish free potatoes place Australian potato producers under pressure to minimise damage by soil insects. Damage most commonly takes the form of holes in tubers. Such cosmetic damage results in complete rejection of tubers in the table market and crisping potato trades, and downgrading for processing potatoes. Some pests such as African black beetle and rice root aphid can affect crop establishment or crop health, thereby having a direct impact on crop yield. As at December 2000, it was estimated that soil pest damage alone, without including cost of insecticides used against them, was almost $2.4m. The state by state breakdown of the importance of the major soil insect pests is given in Appendix 1.

This damage to potato crops and tubers occurs as a result of control measures being inadequate or growers taking no action when, unbeknown to them, pests are present. Seed potato growers also need to produce potatoes with minimal damage and certainly without the presence of soil insect pests, to avoid spreading pests to uninfested areas; for example growers whose farms are free of whitefringed weevil, a non-flying insect.

By their nature, soil insects are difficult to detect. This is because soil is a difficult medium to sample and growers may not always correctly identify soil insect pests. The soil pests are of particular concern where growers use leased land and therefore do not know its history. Routine use of insecticides is likely, whether they are required or not, unless monitoring is shown to be reliable. This project sought to improve the ability of growers or their crop consultants in knowing if crops faced a risk of damage by soil insects and if required, implement appropriate management strategies to minimise or eliminate the risk.

At the start of the project, the team of collaborators defined the main soil insect pests of potatoes in their states in Australia as:

- whitefringed weevil (WA, NSW, VIC, QLD, SA and TAS)
- African black beetle (WA and NSW)
- potato wireworm (VIC)
- whitegrubs (QLD, VIC.)
- rice root aphid (QLD).

This project sought to confirm the distribution and occurrence of these pests and clarify the situation regarding reports of damage by other less well-known soil insects.

With respect to soil insect pests of potatoes internationally, Australia seems to have a greater range of species and a greater prevalence of problems with them than almost any other country (Zehnder *et al* 1994). Of the insects mentioned above, whitefringed weevil and African black beetle are introduced species. Their origins are South America and southern Africa respectively. Whether rice root aphid is a native or introduced species is not certain.

The biology of these pests has been the subject of many studies. In their review of soil insect pests in Australia, Allsopp and Hitchcock (1987) included most of the soil insect pests of potatoes. They provided notes on distribution, identification, importance, basic biology, control methods and research. The report also included a literature review. The identification and control of some of the pests that are the subject of this study occur in Tasmania and have been reported by McQuillan and Ireson (1987). An aid to identifying the range of soil insects that may be associated with potato crops in Western Australia has been produced (Learmonth, 1988).

The introduction and spread of whitefringed weevil has been summarised by Gough & Brown (1991) and these workers together with Matthiessen (1991), have reported on the biology and management of this pest also. Some previous work has been undertaken on developing monitoring guidelines for assessing abundance of whitefringed weevil (Learmonth, 1999).

Fay *et al* (1989), Rogers & Fay (1991) and Learmonth & Matthiessen (1990) have reported on reducing the abundance of whitefringed weevil by crop rotation. Details on the effects of insecticide on whitefringed weevil have been reported by Matthiessen & Learmonth (1995).

King *et al* (1981 (a) to (d)) and Matthiessen & Ridsdill-Smith (1991) have studied the biology and management of African black beetle. Matthiessen & Learmonth (1995 and 1998) have reported on investigations on the management of African black beetle in potato crops.

Horne & Horne (1991) reported on the biology and insecticidal control of potato wireworm. Their studies included the use of cut sections of potato tubers as bait to assess the abundance of larvae. Information derived on pest abundance was used to recommend control measures. Although not mentioned during a review of pests that would be included in the present study, Goodyer (1983) reported that wireworms and false wireworms can damage potatoes in NSW.

For a review and bibliography on whitegrubs of Australia, see Allsopp and Hitchcock (1987). Compared to other soil pests of potatoes in Australia, comparatively less detailed information is available on this group of species. The main reason for this would appear to be that this group of insects is not responsible for consistent losses to potato crops. When damage is high, it may be restricted to a few farms only. The main species implicated in damage to potato crops are red and yellow-headed pasture cockchafers, and unidentified species in NSW and QLD.

Rice root aphid (RRA) has been reported to be a problem only in potato crops in Lockyer Valley, Queensland (Coleman & Duff, pers. comm.). Overseas studies on rice root aphid report the pest causes only a slight decline in yield in potato crops ranging from 1.5 to 5.85% (Ram and Misra 1998). Field observations in one infested crop in Queensland at around four to six weeks prior to harvest, were that leaves turned pale green and were generally in patches throughout the paddock. It was unclear what impact this pest might have on yield locally as no data have been collected. Any yield reduction may be manifest as reduced size of tubers, but these could still be sold depending on the market demand at the time of harvest. No external symptoms on the tubers of an infested crop have been observed. Ridland (1988) studied the biology of rice root aphid in southern Australia. In potato crops in Queensland RRA was found only during autumn when crops approached maturity and tubers were starting to fill out. Large numbers of dark aphids could be found on the roots and rhizomes of the plants affecting the uptake and storage of water and nutrients vital for plant growth and tuber development. The aphid was most prevalent on heavier clay soils. This was thought to be because such soils have a higher moisture holding capacity compared to sandier soils where rice root aphid has not been reported to be a problem in potatoes (Coleman & Duff, pers. comm.).

The project had the aim of defining the risk of damage to potato crops from the better known soil insect pests. For other less well understood pests such as cockchafers and the rice root aphid, the project had the objective of clarifying their identity, pest status and where appropriate investigate management options.

In conjunction with the studies in defining risk of damage, confirmation of the efficacy of currently registered insecticides (Table 1) and trials to assess new insecticides and methods of application for the major pests were undertaken. Where possible, assessment of the efficacy of insecticide for other pests was also made.

To assist growers and consultants in monitoring and managing soil insect pests of potatoes, it was also proposed to collate information on soil insects generated from the current project to produce a Management Manual. The Manual would be designed to have application for all potato growing regions of Australia, not just those in which this project was undertaken.

Table 1. Insecticides registered for the control of the major soil insect pests of potatoes as at the commencement of the current project.

Insecticide	Pest	State	Application details
fipronil	whitefringed weevil	All States	Apply as a broadcast spray to the surface of the soil and incorporate to a depth of 15 cm prior to planting.
	wireworm (various), mole cricket (various)	All States	
chlorpyrifos	African black beetle	NSW, WA	Pre-plant and top up at hill up.
		WA	APVMA Permit PER6585 to protect growing crops from fly-ins of adults. Permit expires 1 Dec 2005.
	whitefringed weevil	NSW, Vic, WA	
	wireworm	Vic	
alphacypermethrin	garden weevil	WA	Request to APVMA to renew Permit PER4926.
phorate	wireworms	All States	
metham as sodium salt	*	NSW, QLD, SA, Vic, WA	

*Metham is not registered specifically for soil insect pests.

(A) DETERMINING RISK OF DAMAGE

Materials & Methods

Risk of damage to potato crops from soil insect pests was studied by monitoring to assess the abundance of pests in pasture or soil prior to planting potatoes. This was followed up with an assessment of crop damage – both direct and indirect reductions in yield. Direct effects would be expected as a result of early stem damage by African black beetle adults and through reduced crop vigour by rice root aphid. Indirect effects would occur from rejection of damaged tubers. The exceptions to measuring pest abundance in soil before planting were monitoring flights of African black beetle adults to asses the likelihood of invasions during crop growth, and rice root aphid where the influence of the previous crop on insect abundance was considered. Table 2 summarises the monitoring methods for each pest or pest group agreed to by the research team at the commencement of the project.

Table 2. Sampling methods proposed at the commencement of the project to estimate insect abundance to determine risk of damage to potato crops in Queensland (QLD, north, N & south, S), New South Wales (NSW), Victoria (VIC) and Western Australia (WA).

* PEST	SOIL SAMPLING	BAIT	TRAPS - adults		PLANT
	spade grid sampling		LIGHT	PITFALL	SAMPLING
WFW	NSW & QLD to use best bet, least time method as first up choice, then review based on results. VIC - #clustered grid WA - grid	–	–	✔ NSW, QLDN, WA	–
ABB	grid sampling (NSW, WA)	–	✔ NSW, WA	✔ NSW, WA	–
WG	grid sampling (QLD)	–	✔ QLDN	✔ QLDN	–
PWW	–	✔ VIC	–	–	–
R/YHPC	grid sampling (VIC)	–	–	✔ VIC	–
RRA	–	–	–	–	QLDS - Select farms Survey plants: adjacent areas in-crop (roots) on potato plants

* PEST abbreviations of names: WFW = whitefringed weevil, ABB = African black beetle, WG = white grubs (cockchafer larvae), PWW = potato wireworm, R/YHPC = red- and yellow- headed pasture cockchafers, RRA = rice root aphid.

✔ = sampling method to be used/tested.

See text for details.

1. Monitoring methods

Identifying soil insects

During pre-crop soil sampling to measure insect abundance or during hand harvests at crop maturity to assess yield loss, specimens of pests were collected whose identity was not known. Large whitegrub larval specimens were collected at potato harvest and some were preserved in 100% alcohol for DNA analysis. An attempt was made at breeding others through to the adult stage by placing advanced stage larvae in trays with soil and sod from the field and cut potato tubers. Other specimens were dispatched direct to taxonomists. A complete list of soil insects mentioned in this report is given in Appendix 2.

Soil sampling

The abundance of most of the soil insect pests was assessed on the basis of soil sampling using a 15 cm spade and to a depth of around 20 cm. Thus sampling was area based, each unit being 0.0225 per m^2. Samples were collected either on an evenly spaced grid with a maximum of 100 sampling units collected, or as clustered sampling. For the regular sampling method, the actual number of units examined per paddock depended on the size and shape of the paddock. For clustered sampling, the method involved sampling at 9 evenly placed locations across a paddock, with each location being a cluster of 6 to 9 samples, making a total of up to 81 sampling units. These two sampling methods were compared on one occasion in a paddock in WA.

All whitefringed weevil sites in Victoria, with one exception, were assessed in the pasture phase. That one site and most of those in WA were assessed after plowing first.

Soil was examined for insects in the field by either hand sorting the soil over a metal tray, or shaking soil slowly off the spade. Insects were identified in the field or kept for identification, and counted.

The selection of farms for sampling soil insect pests was undertaken by a variety of ways. A flyer describing the project invited growers to contact members of the research team to check their paddocks prior to planting potatoes. The main means of selecting farms was based on contact with growers at a local level, usually those growers in risk areas or who had experienced problems with soil insect pests previously.

Bait

Horne & Horne (1991) have described the details of the bait sampling method using potato tubers for assessment of the abundance of potato wireworm. Cracked maize baits were also used to monitor the abundance of surface-active plant feeding beetles. This method was also used to help with pest identification. The bait consisted of a mixture of 125 ml peanut oil and 100 ml chlorpyrifos, and 2.5 kg of cracked maize. A handful of bait was placed on the soil surface near each buried potato bait. Baits were inspected for wireworms 3 days after placement.

A cluster of five potato baits was placed at four sites within a field known for wireworm activity. Potatoes were buried to a depth of 20 cm and checked for wireworm adults one week after burial. Baits were placed at each corner of a 5 m x 5 m grid and in the middle of the grid.

Light traps and emergence traps

For African black beetle, the only pest where the flying adult stage is also capable of damaging potato stems and tubers during crop growth, flight activity and therefore the potential for crop invasion was monitored with light traps. The damaging stage for all other whitegrub species was assumed to be the larval stage. Even though it had been reported that adults of potato scarab (*Cheiroplatys latipes*) damage potato tubers (Allsopp & Hitchcock, 1987), this activity has not been reported commonly.

Also light traps and emergence traps were used to clarify the identity of larvae of whitegrubs found in potato crops. Details on the design and installation of the type of light trap used in this study are given in Appendix 3. The emergence trap used in this study consisted of a 100 L opaque plastic drum with one side removed. The drum was placed on the ground such that the cut away side faced the ground. Any beetles emerging from the soil would fly into a transparent collecting container placed on the side of the plastic drum. Ten emergence traps were used in pasture that had been infested with whitegrub larvae. These traps were used also to collect wireworm adults.

In Far North Queensland, one light trap was located at Tolga next to a canefield and it was cleared twice weekly. This trap was in place from January to April 2002. In 2003, two new traps were placed at two sites in the Tolga area. One trap was placed at the same site as the previous year and the other was placed close to pasture on a different property. Trap clearance procedures were similar to the previous year.

Insect samples were taken back to the laboratory and sorted. All whitegrub adults were preserved in alcohol and labelled. Whitegrubs suspected to be pests were pinned and identified. Samples were sent to Keith Chandler at Bureau of Sugar Experiment Stations, who forwarded them to Kerry Nutt in Brisbane for DNA extraction.

In WA, three light traps were placed across the Busselton area where African black beetle invasions of potato crops are reasonably common. Potato farmers checked traps on a weekly basis and advised the number of beetles caught. This information was collated and supplied by email and fax to farmers servicing the light traps as well as other growers in the Busselton region.

Pitfall traps

Pitfall traps used in previous studies on African black beetle (Matthiessen & Learmonth, 1998) were used to monitor crawling activity of adult beetles. For other suspected beetle pests, the traps were placed in paddocks as a means of collecting beetles to aid in their identification.

2. <u>Factors affecting risk of damage</u>

Land use history

The effect of previous land use on abundance of soil insect pests was clarified on an opportunity basis depending on growers' individual situations.

For whitefringed weevil in Far North Queensland, peanuts had been implicated with damage to subsequent potato crops. On one farm, peanuts and forage sorghum rotations could be compared for their effect on tuber damage.

For rice root aphid, no guidelines for monitoring were available. As it was expected that the previous land use history might be the major factor in aphid abundance, farmers who had experienced problems with the pest were interviewed to help develop a strategy for risk assessment. A number of sites were regularly checked for RRA during the autumn/winter cropping period in the Lockyer Valley, Queensland. For this, the root system of a number of plants including potato and nearby plants suspected of being infested were examined.

At one site in the Kooweerup area in Victoria, a longer-term approach was taken to control red-headed pasture cockchafer (RHPC) through a combination of cropping practice and cultivation. RHPC numbers were assessed as high (150 to 200/m^2) in early 2004 and treatment was required. One paddock to be planted in the next year was first rotary hoed, and then planted to rye-grass for grazing. The rye-grass was then rotary hoed and planted to potatoes in January 2005. No harvest assessment will be available before this report is submitted.

Cultivation

The effect of cultivation on abundance of soil insect pests was considered to be a management option principally for the large whitegrub larvae observed in some eastern state's cropping regions. This aspect was examined also on an opportunity basis with growers.

Insecticide use

Potato growers planning to apply a soil pesticide on farms to be used to collect data on pest numbers before planting and damage levels at harvest, were requested to leave a portion of the crop untreated. The size of this untreated area was not set, but often the area requested was 20 m wide by 50 m long. Where such areas were established, the damage level in this area was compared to damage levels in an adjacent treated area of equal dimensions. In this way it was possible to examine relationships between pest abundance and subsequent damage as well as assessing the effectiveness of different pesticides on pest control.

3. <u>Assessing crop damage</u>

The level of damage by insects to potato tubers at crop maturity was assessed to:

- develop damage threshholds based on precrop soil sample estimates of pest abundance;
- clarify the pest status of some soil insects;
- compare different insecticides in screening trials;
- indicate the level of control achieved by pesticide use in commercial crops by comparison with an adjacent small untreated plot.

Where relevant, the pest causing damage was confirmed by in-crop observations prior to or during the commercial harvest.

Usually, estimates of damage to crops were based on detailed samples. This involved using a garden fork to collect tubers from a number of sampling units of 2 m of crop row each, with a minimum of 5 units per observation. This number was increased to ten sampling units per treated and untreated area in the damage threshhold study. Tubers were examined individually by hand.

Information collected included the number of tubers of marketable size (> 30 g) and whether they were damaged by insects. Potato tubers were assessed as being damaged if the hole made by an insect was deeper than could be removed by a vegetable peeler. Holes shallower than this may still allow the tuber to be sold even if a load was downgraded if the proportion of such tubers was high. Holes deeper than this would constitute rejection in the table market trade or if used for processing, would incur a penalty.

From this data, the proportion that was damaged by insects could be calculated. Where feasible, tubers were also weighed to obtain estimates of yield. Tubers that would have been rejected for other reasons such as greening, cracked, mis-shapen, small size or disease were noted also.

Sometimes it was more appropriate to assess losses caused by insects based on observations on the grading chain of the commercial harvester. This was undertaken in consultation with the farmer. Naturally these estimates were less accurate, but from the point of view of recording whether farmers were satisfied with the level of damage, this method was considered satisfactory.

Queensland

Results

Whitegrub identification

Whitegrub adults collected in the light traps in late January and in February at Tolga were identified as *Lepidiota laevis*. DNA was also extracted from adult specimens and cross-referenced with DNA extracted from larvae collected at this site. The larvae were also *L. laevis*. Gough and Brown (1988) speculated that the whitegrubs in their trials near Atherton were *L. laevis*, and not *Lepidiota frenchi*, as they had recorded *L. laevis* adults in light traps nearby but were unable to identify the larvae to species.

Adult whitegrubs were also collected at harvest at Ravenshoe and identified as *Sericesthis sp*. (Ross Storey, pers. comm.). Adult whitegrubs were also caught in the emergence traps in December following the first storm for the season. These adults were also identified as *Sericesthis* sp. This species does not appear to be an economic pest of potatoes. A search of the Australian Plant Pest Database did not indicate this genus to be a pest of potatoes.

Whitefringed weevil

At all sites where pre-plant soil sampling showed that the abundance of whitefringed weevil larvae was low, there was not a significant difference in tuber damage at crop maturity between treated and untreated blocks (Tables 3 & 4). On some properties where pre-plant counts indicated low numbers of WFW larvae, farmers did not apply soil insecticide. In such crops, tuber damage was very low (Table 4). In contrast, some growers treated the entire field even though the abundance of WFW larvae was determined to be low. In these situations it was not possible to assess the possible effects of these low pest abundance situations on damage. Interestingly, on a third of occasions when WFW counts were zero at pre-plant monitoring, some damage was recorded at harvest in untreated crops. However, damage never exceeded 4% in such areas.

Table 3. Average no. WFW at monitoring and average % damage to tubers at harvest in treated and untreated areas in 2002.

Site	No. WFW at pre-plant monitoring	% WFW damage at harvest (treated)	% WFW damage at harvest (untreated)
Beantree Rd	0	0	0
Tolga scrub	0	0	0.4
Northey Rd (sugarcane)	0	0	0
Northey Rd (Forage. sorghum)	N/A	N/A	0
Northey Rd (peanut)	0.89	0	3.9
End Northey	0	N/A	2.5
Ravenshoe	0	N/A	0

At one site where the pre-treatment count for whitefringed weevil was high, the farmer was not confident to leave any soil untreated. This was also the case in the adjoining field where no weevil larvae were recorded. Damage to peanut plants caused by larvae severing the taproot could be seen on the peanut crop which preceded the potatoes and at a time when the crop was not water stressed. Symptoms of the damage were wilting plants, yellowing foliage, premature senescence and eventually dead plants amongst the green, growing crop. Peanut plants in the adjacent field did not suffer from weevil damage. This field was planted to forage sorghum as a green manure crop the previous summer and no weevil larvae were recorded there during pre-plant monitoring. At harvest, even though the farmer had treated with fipronil because of the damage to the peanut crop, there was minor damage to the potatoes and two weevils were recorded. No damage or weevils were recorded in the crop sown to forage sorghum the previous summer (see Figs. 1 and 2).

Table 4. Average no. WFW at monitoring and average % damage to tubers at harvest in treated and untreated areas in 2003.

Site	No. WFW at pre-plant monitoring	% WFW damage at harvest (treated)	% WFW damage at harvest (untreated)
Northey Rd (peanut)	20	0.7	N/A
Northey Rd (Forage. sorghum)	0	0	N/A
East Barron	0	0	N/A
Ravenshoe 1	0	N/A	3.1
Ravenshoe 2	1	N/A	1.6
Ravenshoe 3	0	N/A	3.1
Atherton	0	N/A	1.8
Beantree Rd	N/A	1.6	0.4
Beantree Rd	N/A	1.8	0.3
Beantree Rd	0	0	N/A

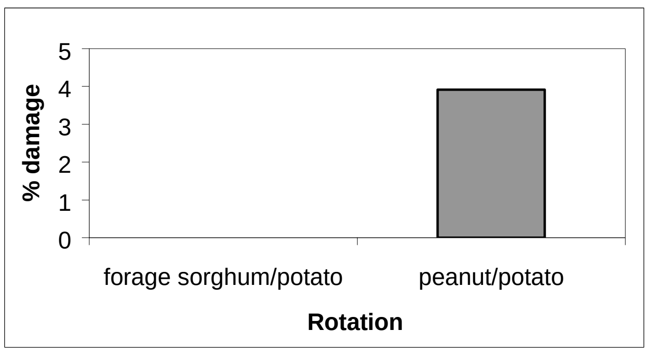

Fig. 1. Difference between peanut and forage sorghum rotations on damage (%) by whitefringed weevil in Far North Queensland, 2002.

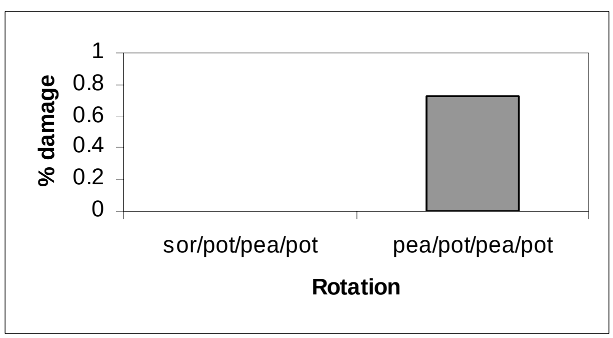

Fig. 2. Difference between peanut and forage sorghum rotations on damage (%) by whitefringed weevil in Far North Queensland, 2003.

Part of the potato cropping region on the Atherton Tableland had been found to be free of damage by whitefringed weevil in earlier studies (Fay and De Faveri, pers. comm.). However, more recently WFW damage has been suspected to be occurring in the Ravenshoe area. The implications for this are that growers in other areas such as east Barron that are yet to see WFW damage should, as far as practicable, try to ensure this region remains free of the pest through consideration of movement of potato growing equipment. Growers in this region should also be encouraged to undertake pre-crop sampling in the knowledge that it is highly probable that treatment for WFW will not be required.

Whitegrubs

A total of three whitegrub larvae were recorded at the Beantree Rd property in 2002. This equates to a density of 1.7/m^2, a level which indicated that treatment was not necessary. However, the harvest result showed a higher level of damage than is acceptable (Fig. 3). In addition, quite a few larvae were observed during the damage assessment of tubers at crop maturity. There was slightly more damage in the area treated with fipronil than in the untreated area. Fipronil has a reputation for poor activity against cockchafers and the difference in damage level between untreated and the fipronil area may be explained by variability of insect abundance across the sampled area.

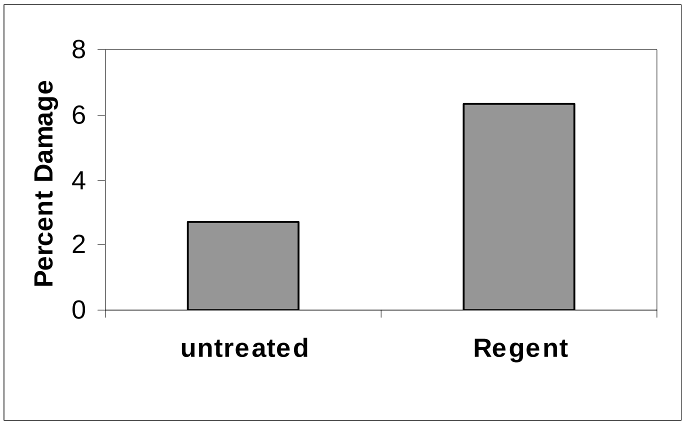

Fig. 3, Percentage whitegrub damage to potato tubers in untreated and insecticide treated (fipronil) areas on Beantree Rd, FNQ, 2002.

In the subsequent year, no whitegrub larvae were recorded at pre-plant monitoring. Only one crop was sampled at this site, although harvest assessments were conducted on three crops. Results for the two crops where pre-crop soil sampling for larvae was not undertaken, indicated low levels of whitegrub damage in both treated and untreated areas. The third crop, which had been monitored, had no whitegrub larvae present at harvest and no damage was recorded. However, the farmer was not prepared to leave an untreated area as this field was adjacent to the previous season's crop, which had 7% damage (see Fig. 3).

At a Ravenshoe paddock where potatoes were to be planted, pre-crop sampling estimated the whitegrub density at 10.1 larvae per m^2. After this paddock was cultivated with a rotary hoe, the density fell to 0.94 larvae per m^2 (Table 5). At harvest there was little whitegrub damage (Fig.4).

Table 5. The abundance of whitegrub and wireworm larvae before and after cultivation at Ravenshoe, FNQ, 2002.

	Number of whitegrubs per m^2	Number of wireworms per m^2
Pre-cultivation	10.1	0.78
Post-cultivation	0.94	0.52

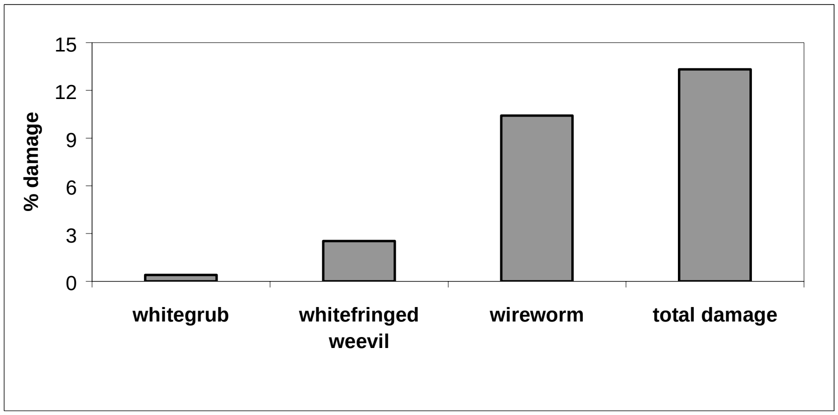

Fig. 4. Percentage damage to tubers by soil insects on untreated potatoes at Ravenshoe, FNQ, 2002.

Wireworms

Wireworms were difficult to detect at pre-plant monitoring. Although low numbers were recorded at Ravenshoe in 2002 and 2003, thus indicating low risk (Table 6), all crops sustained damage in the range 3% to 10%. The latter higher level of damage is an indication of the potential for wireworms to be commercially significant in some situations in this area.

Table 6. Number of wireworms (larvae) at pre-plant soil sampling and percent damage to potato tubers at harvest, FNQ, 2002-03.

Site & harvest year	No. wireworms per m^2	% damage
Ravenshoe (2002)	0.5	10.4
Ravenshoe 1 (2003)	1.5	3.1
Ravenshoe 2 (2003)	0.5	3.7
Ravenshoe 3 (2003)	0	6.0

Potato baits were trialled for pre-crop monitoring, but no wireworm larvae were recorded on the baits. Cracked maize baits were also trialled as adult attractants, but these were unsuccessful based on the fact that numerous wireworm adults were captured in emergence traps used for whitegrub adults, described previously. Although not confirmed, it is thought that these wireworm adults were the same species as the wireworm larvae causing the characteristic damage to tubers - circular holes approximately 4 mm diameter. Sometimes, the wireworm larva was found protruding from the damaged tuber.

Other soil insect pests - North Queensland

One *Ataenius* sp. whitegrub larva was recorded burrowing into potatoes at Ravenshoe. There are 55 species of this genus described in Australia and larvae of *A. picinus* have been recorded feeding on potato. This species has been recorded at Ravenshoe previously (Stebnicka & Howden 1997).

Damage inconsistent with that of other soil pests has also been recorded at Ravenshoe (Fig 5). The damage was deeper and less uniform than caused by WFW, much larger than wireworm damage and not rat like which is similar to whitegrub damage. The damage caused ranged from 0.2% to almost 6%, and combined with all the other insects, total damage ranged from 5% to almost 11%.

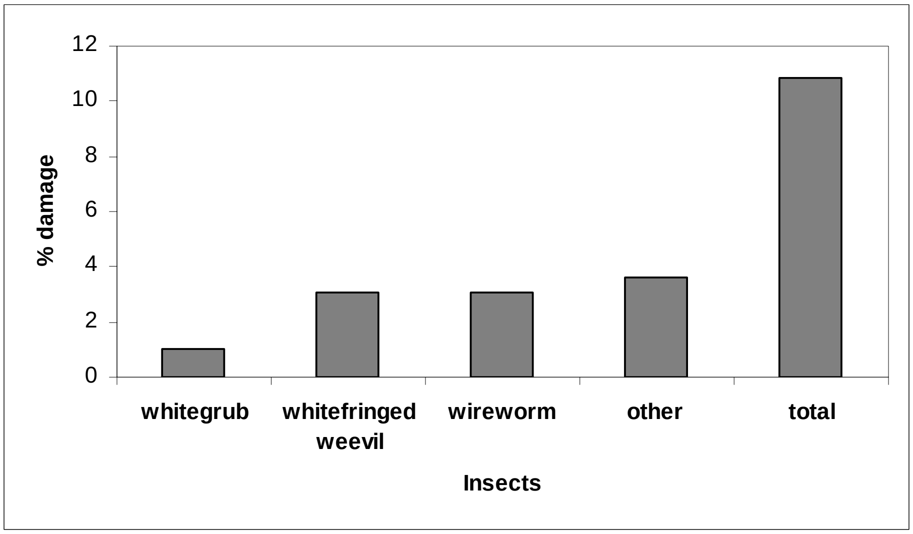

Fig. 5. Percentage damage by soil insects on untreated potatoes at Ravenshoe, 2003

Rice root aphid

Investigations relating to rice root aphid (RRA) were undertaken in the Gatton area of south Queensland, the only area in Australia reporting damage to potato crops by this insect.

One site (Tenthill) known to have had RRA present in previous years was regularly checked. No sign of RRA was detected. However, this pest was found on a different part of the property and only showed up late in the season, once the plants were reaching maturity, about 4 to 6 weeks from harvest. The abundance of the pest declined, probably as a result of the occurrence of a soil borne fungal agent. The Biopesticides Unit within QDPI identified the fungus as *Verticillium lecanii*. Three other sites - at Tenthill, Atkinson's Dam and Glenore Grove - also failed to yield any RRA, even though the Glenore Grove site had a previous history of this root pest.

Due to the elusive nature of this pest during the life of this current project, RRA has only been found on potato (*Solanum tuberosum*), nutgrass (*Cyperus rotundus*) and common sowthistle (*Sonchus oleracea*). It is known to infest *Prunus* species, *Gossypium* species and numerous Poaceae including wheat (*Triticum aestivum*) and rice (*Oryza sativa*), all of which are grown either in the Lockyer Valley or in parts of southeast Queensland.

Thimet ® was used as a pre plant application to soil, by a potato grower to control RRA. Although the crop did not suffer an infestation by the aphid, the possibility exists that some other factor prevented the build up of the pest, for example an infection of the aphids by the fungus *Verticillium lecanii* which was recorded on RRA during this project – see discussion below.

Due to the lack of suitable crops infested with RRA, assessment of possible control measures using available insecticides was not possible. One such insecticide that was to be assessed was the systemic insecticide imidacloprid as a furrow application at planting. However, experience with this insecticide suggests an activity period of only about 4 to 6 weeks. For it to be effective in a 3 month potato crop, the insecticide would need to control RRA in the early stages of the crop. It may have been useful as a foliar application but the cost would have to be weighed against the expected yield reduction, which according to overseas data is only small, up to 5-6%. One grower at Tenthill did indicate that he observed a significant yield reduction but other factors may have been involved, such as mole crickets and wireworms, which can be an issue for Lockyer Valley potato growers from time to time.

Other pests – Southeast Queensland

Growers indicated that mole cricket, black field cricket and wireworms can damage potatoes at times in this region. These insects were not included in the present study.

Discussion and Conclusions

Whitefringed weevil

Pre-crop monitoring for whitefringed weevil can be effective in predicting the likely severity of damage and therefore the need for preventative action. If $\geq$1 WFW larva / m^2, then treatment with a soil insecticide is considered necessary. If <1 WFW larva / m^2 then treatment is not necessary and damage should be less than the estimated Economic Injury Level of 5% (see Appendix 4 for a discussion on Economic Injury Level of soil insect pest of potatoes).

Larval sampling needs to be based on a uniform grid across a paddock. Once 4 larvae are found a grower may decide to treat the whole paddock and not continue sampling. If the grower intends to treat parts of a paddock based on where larvae are found in it, the whole paddock would need to be sampled. Pre-crop sampling appears to be more reliable if carried out at the end of the previous crop, as larvae are closer to the surface.

Previous crop history, planting times and crop rotations should also be considered before planting and deciding to treat. Some paddocks may have a history of high WFW infestations. Planting after legume rotations such as peanuts or white clover increases the risk of WFW damage compared to rotations such as maize, grass pastures and forage sorghum. Crops planted early and subsequently harvested in the cooler months may be at less risk than those planted later, as larvae feed more in the warmer months as they prepare to pupate.

The effect of forage sorghum on WFW should be further investigated. It should be established whether the release of cyanogenic glucosides is causing mortality, or the poor host status alone is reducing fecundity and egg laying.

Potato growers in that region of Atherton Tableland found to be free of WFW, should be encouraged to sample soil before planting potatoes because they have the greatest chance of avoiding insecticide treatment for this pest.

Whitegrubs

Monitoring for whitegrubs appears to be ineffective, as this study has shown that the numbers found at monitoring do not indicate the likely damage at harvest. Also, chlorpyrifos is the only insecticide registered against this group of pests in potatoes, though not specifically for species other than African black beetle. However, it is not thought to be efficacious against *L. laevis* (K. Chandler, pers. comm.). Phorate is registered against wireworms but its efficacy against *L. laevis* is not known. Rotating with less favoured hosts such as legumes (not in WFW areas), and cultivation (rotary hoe), are better options for control or at least suppression of these pests. This was demonstrated at Ravenshoe where there were fewer larvae after cultivation (Table 5).

It appears that the small whitegrub (*Sericesthis* sp.) at Ravenshoe is not a pest of potato, while the aphodiine scarab *Ataenius* may cause some incidental damage.

The biology of *L. laevis* should be studied further and as this pest is known to be associated with sugarcane and pastures on the Atherton Tableland, there may be an opportunity to collaborate with BSES on a joint project. It should be established whether this pest has a one or two-year life cycle, as this has implications for control applications in both potatoes and the crops they are rotated with. Following the sugarcane example, in the short-term there are opportunities for investigating the efficacy of imidacloprid for whitegrub control in potatoes.

Wireworm

An effective monitoring tool for wireworm is required. Further studies should be conducted into germinating seed baits or other baiting options. An action level would then need to be established. Confirmation is required of the wireworm species of relevance to potatoes on the Atherton Tableland, as they are an issue for a small number of growers in specific areas.

Further studies are necessary to identify the pest at Ravenshoe that caused the extraneous tuber damage reported above (see Fig. 5). Investigations should be conducted at earlier stages during crop growth as no insects were found at harvest. It is possible that the size of cavities in tubers caused by early wireworm damage increased in size later as tubers developed.

For a few growers in the higher potato-growing areas, wireworms are an issue, and more work needs to be done on monitoring activity and identifying effective insecticides in potato crops.

Rice root aphid

Once this pest has been identified on a grower's property, it appears that the soil borne fungus *V. lecanii* is able to establish and exert control over RRA. A study by Etzel and Petitt (1992) found that when *V. lecanii* was introduced into a greenhouse crop of squash plants, RRA was virtually eradicated within 4 weeks. This also seemed to occur in the field in the current study. It would also appear that this entomopathogenic fungal organism remains endemic within the soil for a number of years as the RRA has not been seen on that cropped paddock again, even when potatoes are grown there. This has certainly been the case during this project, and therefore limited observations only were possible.

One recent management change to growing potatoes in the Lockyer Valley in Queensland has been the decision to plant later, which could also be contributing to the low incidence of RRA in crops. The main reason for the trend to later planting is to reduce the severity of attack by the important pests melon thrips (*Thrips palmi*) and silverleaf whitefly (*Bemisia tabaci*), which attack crops during the autumn months. By planting later the incidence of these pests is lower. Such delayed planting could also mean reduced abundance of RRA because its development is severely curtailed with lower temperatures (Ridland 1988). This is also the most likely reason why this pest is not an issue in potato crops planted during winter/spring in the region.

Control of RRA was attempted in one crop using the soil insecticide phorate. Although the crop did not suffer an infestation by the aphid, it was not verified whether this was a result of the insecticide or some other cause. The planned activity of investigating control measures for RRA using available insecticides was not possible due to the unavailability of infested sites.

This project did not make sufficient observations to determine the source of RRA infestation in potato crops. The two main possibilities are carryover in soil from a previous crop or immigration into a growing crop by winged adults. The former possibility was clearly the source described by one potato grower who mentioned that a stand of lucerne that was heavily infested with nut grass, was the area where a subsequent potato crop was adversely affected by RRA. If such effects of crop history were confirmed for other rotation patterns, precrop sampling would also play a role in protecting crops from this pest, especially if the relative favourability of different plants is known. Should this be a major source of infestation, the assessment of the efficacy of the systemic insecticides such as imidacloprid as a furrow application at planting should be considered.

It would appear that RRA is only a minor pest of potato crops in the Lockyer Valley and that there could very well be a cyclical pattern to its occurrence as a potato pest. Growers and consultants canvassed on this pest indicated that it may only occur about once every five years which could be a reflection of the longevity of the entomopathogenic soil borne fungus.

With a change in grower practices to planting later and the incidence of the fungal pathogen, this potato pest will most likely remain of minor concern to the majority of potato growers in the Lockyer Valley, Queensland. Should it become a more important pest, clarifying its mode of entry into crops would be relevant to considering options for control such as a systemic insecticide applied in the planting furrow.

Little work was undertaken on other potato pests in southeast Queensland such as wireworms, and mole and black field crickets. Further work could be undertaken on the effect of cropping history, with one grower suggesting millet in a rotation before lablab and potatoes was the cause of a wireworm problem. Other areas for study could include sampling and control methods involving use of the registered bran bait for crickets and a beetle bait for both crickets and wireworm. Such studies to confirm pre-crop sampling and control could include assessing damage levels in untreated areas in insecticide treated paddocks.

New South Wales

Results

Soil insect identification

The most common species of white grub larvae collected from pasture and potato paddocks in the Dorrigo area was the coxsfoot grub *Rhopaea verreauxii* (Blanchard) (Graham Goodyer, pers. comm.). This large pasture scarab was also collected from Robertson in the NSW southern highlands. Other occasional species of white grubs found in Dorrigo were *Dasygnathus globosus*, together with one unidentified specimen in each of the sub families Melolonthinae and Dynastinae (Graham Goodyer, pers. comm.). No adults were recorded from the emergence traps located on a Dorrigo property, which had previously recorded high numbers of *R. verreauxii* larvae.

From Robertson, apart from *R. verreauxii*, one specimen of *Sericesthis nigrolineata* (Boisduval) was collected.

Other soil insects collected in Dorrigo/Guyra in order of incidence were WFW, occasional wireworms, and asilid larvae (robber flies, Diptera) which are predators of scarab larvae.

Field sampling and potato damage

Robertson

Studies were undertaken over three seasons, 2001/2 to 2003/4, to investigate the identity and pest status of soil insects in potato crops in the Robertson area. Unless otherwise stated, pre crop soil sampling of all sites in the Robertson area consisted of examining 5 sampling units of soil, being a square spade 15 cm long at each of 4 sampling stations in the paddock. This relatively small number of sampling units was considered adequate for the relatively small size of crops there. Assessment of soil insect damage to tubers at crop maturity consisted of examining 4 sampling units each being 2 m lengths of row dug by garden fork. The location of sampling sites for assessing insect damage to tubers was in the same area as the sampling stations for pre-crop soil sampling for soil insects.

In the 2001/2 season, three sites were included for pre season soil sampling.

The first site was a 3 ha paddock that had previously been planted to potatoes in 1999/01. The paddock was bare but not worked up when sampled on 12 September 2001. Over 6 stations were sampled and 5 units examined per station. Insects were collected and identified later (see Table 7). WFW was found in high numbers but the experience of the grower was that no soil insecticide was required. At crop maturity, five samples each of 2 m row and in locations corresponding with the pre-season soil sampling stations were examined for insect damage. Tuber damage was less than 3%.

Table 7. The identity and abundance of insects (number/m^2) from soil sampling prior to planting potatoes, at three potato crops in Robertson, NSW, 2001/02 season.

Farm	African black beetle	Whitefringed weevil	Wireworm	White grubs	False wireworm	Moth larvae	Others
Site 1 Bleaker	3.0	22.2	3.0	3.0	0.0	1.5	5.9
Site 2 Fisk	42.2	191.1	46.7	6.7	2.2	4.4	*31.1
Site 3 Hill	33.3	55.6	31.1	0.0	4.4	11.1	*13.3

*These insects were mainly robberfly larvae, Fam. Asilidae, Diptera

The second site was leased land where potatoes had not been grown before. Sampling was undertaken in September 2001, while the area was still under pasture. The crop area was 1 ha. Soil sampling showed ABB, WFW and wireworm were present in very high numbers. The area was not treated with soil insecticide. No tuber damage was seen at crop maturity.

On the third site, potatoes were planted following pasture. Sampling was undertaken in September 2001, while the area was still under pasture. The crop area was 2 ha. Soil sampling indicated that ABB, WFW and wireworm larvae were found in high numbers, with WFW mainly at the lower end of the area. The crop area was not treated with soil insecticide. No tuber damage was seen at crop maturity.

From the above results and discussion with farmers, it appears that WFW was not an issue in the Robertson district during the 2001/02 season, despite the very high numbers of insects found prior to planting. The large variation in insect abundance recorded at the sites was probably related to paddock history and topography. The larval stage of WFW was the most common pest detected in the soil sampling. At Site 3 high densities of WFW larvae were found in clumps, with most of these being early instars. In general, the abundance of other insects was low.

During the 2002/03 season in Robertson, two sites were examined at crop maturity for soil pest damage, as no soil insecticide was used before planting.

At the first site of 4 ha to be cropped to potatoes, the site had not been under potatoes for at least 15 years. Insect damage to tubers was 7.5%, which was considered acceptable given that insecticide had not been applied.

At the second site of 4 ha, which had not been planted to potatoes for about 10 years, tubers were examined for insect damage at crop maturity on 24 April 2003. A damage level of 17.9% was found. This high level of tuber damage was of concern and suggests that more importance needs to be given to pre-crop sampling to prevent such levels from occurring.

Sampling in the Robertson area during the 2003/04 season was carried out on two crops. Again, because growers had already decided that soil insecticides would not be applied, sampling was restricted to an examination of portions of the crop at maturity.

At the first site, potatoes were grown on 4 ha and it had been 15 years since the area was cropped to potatoes. At crop maturity on 5 May 2004, insect damage to tubers was recorded at 4.3%.

At the second site, also a 4 ha paddock, at crop maturity on 5 May 2004, insect damage to tubers was recorded at 2%.

Dorrigo and Guyra.

In 2003, a total of four sites were sampled in Northern NSW, two from Dorrigo and two from Guyra (see Table 8 for details). At each location, one site was treated with chlorpyrifos and the other was left untreated. Insect damage to tubers was not allocated to particular pest species, although some general conclusions were drawn. The results for 2003 are presented in Table 8.

In Dorrigo at Site 1 treated, a paddock which had been under pasture for a number of years, high numbers of scarab larvae including ABB and several pasture scarab species including *R. verreauxii*, were recorded in pre-treatment counts. WFW larvae were also present in high numbers. At Dorrigo Site 2 untreated, which had been under pasture for several years, high numbers ABB, WFW and *R. verreauxii* were also recorded. No other scarab species were recorded, although noctuid larvae were observed in a number of samples.

At Site 1, which had been treated at planting with chlorpyrifos at 800 mL/ha, tuber damage at harvest was still >23% and, surprisingly, was much higher than the untreated Site 2. While there was some WFW damage at Site 1, the overall tuber damage at crop maturity appeared, in part, to be due to heavy mid-season flights by adult black beetle in January-February. This was confirmed by the tuber damage being attributable to ABB adults rather than to larvae (see Fig. 6 for light trap data below for the 2003/04 season). This view was also supported by one of the growers.

In 2004, there were two sample sites in both Dorrigo and Guyra, with untreated areas being nearby crops for one site and untreated areas within the crop for the other site at each location (see Table 9 for details).

In Dorrigo, Site 1 was treated with fipronil and a nearby crop was untreated and sampled for comparison. At Site 2 the field was treated with chlorpyrifos at a rate of 800 mL/ha, except for a central strip which was untreated. In Guyra, Site 1 was treated with chlorpyrifos and a nearby untreated crop was sampled for comparison. At Site 2, the paddock was treated with chlorpyrifos except for an untreated central strip.

Table 8. Soil pest incidence and potato tuber damage Dorrigo and Guyra NSW, 2003.

Site	**Treatment**	**African black beetle per m^2**	**Other scarabs per m^2**	**WFW per m^2**	**% damaged tubers and comments**
Dorrigo site 1	chlorpyrifos	26.7	51.2	55.6	23.7 WFW and scarabs, also ABB fly-ins.
Dorrigo site 2	none	15.6	8.9	22.3	7.5 ABB and some grazing by large scarab, few WFW.
Guyra site 1	none	0.0	53.4	2.2	9.3
Guyra site 2	chlorpyrifos	0.0	0.0	0.0	4.1

The data for the 2004 season are presented in Table 9. In this season, damage to potato tubers at crop maturity was categorised with respect to individual pest species.

In Dorrigo Site 2, sampling in a nearby paddock to the 2003 site did not record any *R. verreauxii*, nor were any collected in emergence traps. Observations of the effects of rotary hoeing in this paddock, however, showed that a number of beetle larvae exposed on the soil surface became prey for birds. The large size of *R. verreauxii* larvae suggests that use of a rotary hoe would likely result in reduced numbers of this insect.

In Guyra, numbers of soil insect pests were generally much lower than in Dorrigo in both seasons. This may be in part attributable to these paddocks (except for Site 1 in 2003) being previously used for potatoes and also to the prevailing drought conditions, as all potatoes in this district are rain-fed. Species recorded were African black beetle and whitefringed weevil, with occasional wireworm and noctuid caterpillars. Except for Site 1 in 2003, few larvae of other scarab species were detected, however, tuber damage, at both sites in 2004 was surprisingly high. In Site 2 in this year, damage in the treated section of the paddock was approximately one-third of that recorded in the untreated section.

Table 9. Soil pest incidence and tuber damage at Dorrigo and Guyra, NSW, 2004

Site	No. African black beetle per m^2	No. other scarabs per m^2	No. WFW per m^2	% ABB & other scarab damage	% WFW damage	% wireworm damage	Total % insect damage
Dorrigo site 1 fipronil	24.9	1.8	0.9	22	0	1.7	23.7
Dorrigo site 1 untreated	2.1	0	2.8	20.1	3.8	0	23.9
Dorrigo site 2 chlorpyrifos	12.2	0.56	0.56	9.1	1.1	0	10.2
Dorrigo site 2 untreated	12.2	0.56	0.56	17.9	0.8	0	18.7
Guyra site 1 chlorpyrifos	4.6	0.0	0.6	11.4	2.9	0.9	15.2
Guyra site 1 untreated	5.6	0.0	0.0	15.1	5.8	0.9	21.8
Guyra site 2 chlorpyrifos	3.3	0.0	0.0	7.8	2.5	1.0	11.3
Guyra site 2 untreated	3.3	0.0	0.0	22.9	5.9	1.0	29.9

Light and emergence traps

A light trap was set up adjacent to one of the Dorrigo survey sites in 2003 to monitor any African black beetle flights, to provide growers with additional warning of potential tuber damage. The light trap catch data is presented in Fig. 6 and shows ABB was the dominant species and that flight activity occurred from August to March, with a peak in late October to December. While activity continued until late March, numbers of beetles captured declined and there was no evidence of significant late season flights.

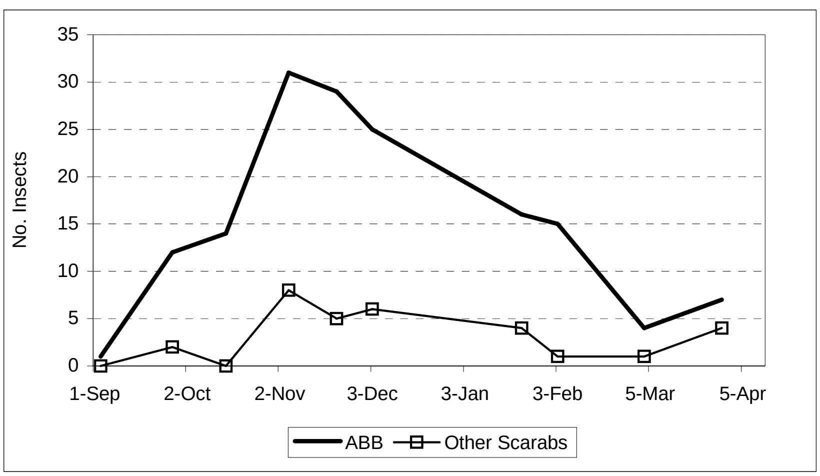

Fig. 6. Number of African black beetle and other scarab adults in a light trap, Dorrigo, NSW 2003/04.

Discussion & Conclusions

Field sampling and potato damage

Robertson

Soil sampling for insects and inspecting tubers at crop maturity was undertaken during the 2001/02 to 2003/04 seasons. The main potential soil insects identified were ABB, WFW and wireworm. Also detected were species of cockchafer larvae, two of which were identified later as *R. verreauxii* and *Sericesthis nigrolineata*. The identity of the wireworm(s) was not clarified, but Goodyer (1983) reported on this group. His discussion included notes and descriptions of wireworms, false wireworms and predatory carabid larvae, the last being included because of their similarity in appearance to wireworms.

Growers in the Robertson were reluctant to use insecticide. This was in spite of the fact that some very high populations of the major soil pests ABB and WFW were detected before planting. In general, this decision to avoid the use of insecticides was shown to be justified with damage levels to tubers usually being less than 5%. The fact that on one occasion a damage level around 18% was recorded, suggests that growers in this region should examine their soil for potato cropping before planting to build experience of the potential for soil pest damage. From this, decisions such as selecting alternative sites for growing potatoes or treating the soil with insecticide may be considered.

Potato growers in the Robertson region are encouraged to undertake pre-crop soil sampling. Also, because some soil insects present there remain unidentified, they are also advised to submit specimens for identification so the gaps in knowledge of pest species in this region may be filled. For the pests species ABB and WFW that have been identified there, the Management Guide planned for soil pests of Australian potato crops will provide broad information on their life cycles. Some damage to potato tubers was seen that was thought to be due to *R. verreauxii.*

Potato growers in the Robertson region regard WFW as a minor pest. This has been ascribed to the ability of potato growers to implement cultural practices to manage the problem. The main management practice implemented is to monitor soil moisture and ensure irrigation is undertaken to maintain soil moisture and minimise tuber damage due to WFW. Results obtained from the tuber damage assessments at harvest indicate that soil insect pests will occasionally be an issue.

The time taken to carry out the pre-season soil sampling was high. It was estimated to take 6 person hours per paddock for the pre-crop sampling. This is due to the type of soil sampled. Robertson soils are very well structured but at times can be cloddy. These clods needed to be broken down to see if any insects were present. This is very time consuming, but the sampling may be made easier if it is timed to coincide with cultivation of the paddock. The size of the weevil larvae can be very small and care must be taken not to miss any.

Dorrigo and Guyra

Some relationships between insects and damage to potato tubers are apparent from the two years' monitoring in these districts in northern New South Wales. First, sites that were being used for the first time after being under pasture for a number of years, consistently recorded higher numbers and a greater diversity of potential soil pests than sites that had recently been used for potato production. Second, there was some correlation between the number of soil insects recorded at pre-planting and the level of tuber damage at harvest in untreated sites. There were some exceptions to what was expected, but most sampling gave a good indication of pest pressure. Third, there was a trend that, where directly comparable data was available, sites treated with chlorpyrifos at a rate of 800 mL/ha at planting had lower levels of tuber damage at harvest. Fipronil applied at 500 mL/ha was, as expected, ineffective against scarab larvae. It was confirmed that tuber damage could occur as a result of adult ABB adults flying into crops later in the season.

WFW was recorded in Dorrigo and Guyra, however numbers were generally low and damage attributable to it was minimal. Its distribution in paddocks was more clumped than were scarab larvae, confirming the need to sample or check across the entire extent of paddocks.

Prior to these investigations, African black beetle was known to be a major pest of potatoes in Dorrigo but not Guyra. Our data suggest that damage by black beetle larvae and adults can be significant in both districts. In Dorrigo, severe tuber damage was attributed to "fly-in" adult ABB in January-February. Clearly this damage cannot be predicted by pre-plant monitoring and requires both flight monitoring via light traps (or observation of beetles flying around lights) and the registration of effective pesticide(s) targeted at this stage of ABB attack.

The high numbers of the large pasture scarab *Rhopaea verreauxii* recorded in pre-treatment counts at one site was interesting but was probably a result of the paddock being under pasture for a number of years. Little damage could be directly attributed to this species at Dorrigo but damage was recorded at Robertson in 2003. *R. verreauxii* is therefore a species that will be included in the potato pest Management Kit. However, its primary host in these districts is pasture and it is also likely that because of its large size, normal tillage operations, particularly rotary hoeing, could reduce its abundance in subsequent seasons.

In a number of sites, larvae of robber flies (Diptera: Asilidae) were collected. These are reported to be predators of scarab larvae. In order that such beneficial species are not mistaken as pests, they will also be included in the potato soil pest Management Kit.

Victoria

Results

Redheaded pasture cockchafer

A high risk of damage was assessed when numbers of cockchafers were over 100/m^2. The reason for selecting some of the sites was because they were immediately adjacent to and had a history identical with, other paddocks where potato crops had 20 – 30% damage in the year before the trial.

Rotary hoeing alone significantly reduced the cockchafer population (Table 10, see Farmer 1 a 2001) but, from such a high level, was not sufficient to eliminate risk. Chemical treatment with chlorpyrifos sprayed on bare ground and incorporated was effective when applied before planting. A final site included in this study, Farmer 4 c, demonstrated that a combination of use of a rotary hoe and cultivating a crop other than potatoes before actually planting a potato crop, can reduce cockchafer numbers. A potato crop to be planted at this site will not be harvested until after the completion of this project.

Table 10: Summary of results of pre-crop soil sampling in potato crop areas for redheaded pasture cockchafer during the project, Victoria.

Farmer	Date	History - 2 years	Min/Max / sq m	Samples with pests	Risk	Advice	Action	Tuber damage
1 a	24/6/01	Pasture	50/200	8/8	High	Rotary hoe then re-assess.	Followed	Less than 0.5%
	1/7/01		25		High	Lorsban		
1 b	23/9/03	Pasture	0	0	Low	No action	Followed	Less than 1%
1 c	23/9/03	Pasture	0/10	1/4	Low	No action	Followed	Less than 1%
2	9/7/02	Pasture	0	0/10	Low	No action	Followed	No damage
3	30/8/02	Pasture/ ploughed	0	0/13	Low	No action		Less than 1%
4 a	1/9/03	Pasture	100/185	4/4	High	Lorsban	Followed	Less than 1%
4 b	2/10/03	Pasture	150/170	4/4	High	Lorsban	Followed	Less than 1%
4 c	2/10/03	Pasture	150/200	4/4	High	Rotary hoe, Rye grass	Followed	Planted 2005
	Dec/04	Rye grass	0/5	1/10	Low	No action	Followed	

Potato wireworm

Only one crop was included in this study, but it showed that use of baits allowed the pest distribution to be mapped. Control measure suggested to the farmer were followed and an acceptable level of crop damage resulted (see Table 11).

Table 11: Summary of results of pre-crop soil sampling in potato crop areas for potato wireworm during the project, Victoria.

Farmer	Date	History - 2 years	Min/Max / sq m	Samples with pests	Risk	Advice	Action	Tuber damage
1. Sampled by baiting	16/5/02 to 27/6/02	Pasture	0/30	6/12 patchy	High	Regent/ Lorsban/ Untreated	Followed	Less than 2%

Whitefringed weevil

A series of field trials over three years provided excellent control of whitefringed weevil in commercial crops (Table 12). These results include recommendations for no action and for insecticide treatment. There were also successful recommendations to avoid planting in high-risk areas. Given that the seed crops involved in some cases were relatively small plantings, the avoidance of high-risk areas was a realistic and practical option as it was not necessary to plant the entire paddock.

Table 12. Summary of results of pre-crop soil sampling in potato crop areas for whitefringed weevil during the project, Victoria.

Farmer	Date	History - 2 years	Min/Max per sq m	Samples with pests	Risk	Advice	Action	Tuber damage
1 a	24/6/01	pasture	0/45	7/8	Low (top)	Regent patches	No action	Little – no damage
1 b	5/9/01	pasture	3/45	3/3	Medium	Regent patches	No action	Low damage at top
1 c	30/5/02	Pasture	0/15	3/9	low	No action		Not planted
1 d	30/5/02	Pasture	0/35	9/12	Medium	Regent patches		Not planted
1 e	20/6/02	Pasture	0/80	10/12	High	Treat ¾		Not planted
2 a	30/8/01	Pasture/ rye	0/50	8/10	High	Regent 1.5 x 2	followed	Very low V. high in control
2 b	30/8/01	Pasture	10/55	9/9	High	Regent	Regent	Acceptable
2 c	5/9/01	Maize/ rye	0/5	2/6	V. low	No action	No action	No damage
2 d	13/9/02	Pasture	0/35	7/8	High	Regent	followed	Less than 1%
3	13/9/02	Pasture	0/75	7/8	High	Regent	followed	Less than 1%
4	13/9/02	Pasture	15/105	8/8	High	Regent	followed	Less than 1%
5 a	23/9/03	Pasture	0	0	Low	No action	followed	Less than 1%
5 b	23/9/03	Pasture	0	0	Low	No action	followed	More than10%

There was a stand-out failure of the pre-crop sampling to predict damage by whitefringed weevil, and this was in a crop of Farmer 5b (Table 12). There were two major differences between this situation and all others. These were: (1) the sampling was done after the pasture had been turned over with the first plowing to prepare the paddock for planting and (2) the crop was harvested much later than was expected due to factors totally beyond the control of the grower. During such "ground storing", WFW larvae move within the soil and damage to tubers increases.

Discussion and Conclusions

Redheaded pasture cockchafer

Pre-crop soil sampling for this pest successfully identified paddocks at risk from damage. In one case where insect numbers were considered high enough to present a high risk of crop damage, use of the insecticide chlorpyrifos protected the crop. This result provides information to support a request to registration authorities that this use be available to potato growers.

It would be much better for farmers if they did not need to rely on the regular use of persistent, broad-spectrum insecticides. One aim of this work in Victoria was to identify whether or not there was a non-chemical alternative for growers prepared to think ahead. The final site monitored on farmer 4 c (Table 10) demonstrated that such control was possible. Further work along these lines would be very useful for the industry.

The occurrence and pest status of other species of cockchafer such as yellow-headed pasture cockchafer require clarification in the Victorian potato growing regions.

Potato wireworm

Trials with potato wireworm demonstrated the same results as that recorded by Horne and Horne (1991). Baiting in the pasture phase before potatoes are planted can indicate the presence of potato wireworm and the percentage of baits damaged indicates the likely level of damage. Regent ® (fipronil) is effective if applied before planting and incorporated. The only cultural control option available to growers at present is to avoid high-risk areas when they are identified.

Whitefringed weevil

As with redheaded pasture cockchafer and potato wireworm, the advice provided to potato growers after soil sampling before potatoes are planted provided growers with reliable information on whether treatment to protect crops is required. One notable exception to this satisfactory result was where sampling was undertaken after the paddock was worked up in preparation for a potato crop and the crop was left in the ground much longer than was expected. This suggests that the sampling is much more efficient in pasture and that a low level population may develop into a damaging population if the crop remains in the ground while weevil larvae grow and mature. When no other food source remains, as in a potato crop after senescence, then the potato tubers will be at greatest risk.

These results for reducing damage to potatoes in Victoria suggest that the best results will be achieved when growers plan ahead and look at assessing risk and applying control measures well before crops are planted.

Pre-crop soil sampling

For most soil insect pest situations for potato cropping in Victoria, there is sufficient knowledge to be able to undertake pre-crop soil sampling and issue reports to growers on the results and include appropriate recommended actions. An example of such a report is given in Appendix 5. Whether this type of information is gathered by consultants or undertaken by the grower, such activity is encouraged in those areas in Australia where soil pests are a threat.

Western Australia

Whitefringed weevil

Results

On one occasion, a comparison was made of the two proposed sampling methods for WFW larvae. These methods were clustered sampling and a regular grid sampling (see Fig. 7). For the clustered sampling, 6 sampling units were selected in a cluster and 9 such clusters were sampled over the paddock, with a total 54 sampling units examined. For the grid sampling, sampling units were spaced regularly across the paddock, with a total of 96 sampling units examined in a 6 x 16 transect pattern. These two methods are indicated by the array of squares and bars in Fig. 7 which also displays the numbers of whitefringed weevil larvae found. With the exception of finding some larvae on the western side of the paddock using the grid sampling method, the pattern of the distribution of larvae was similar for the two sampling methods, as was their abundance.

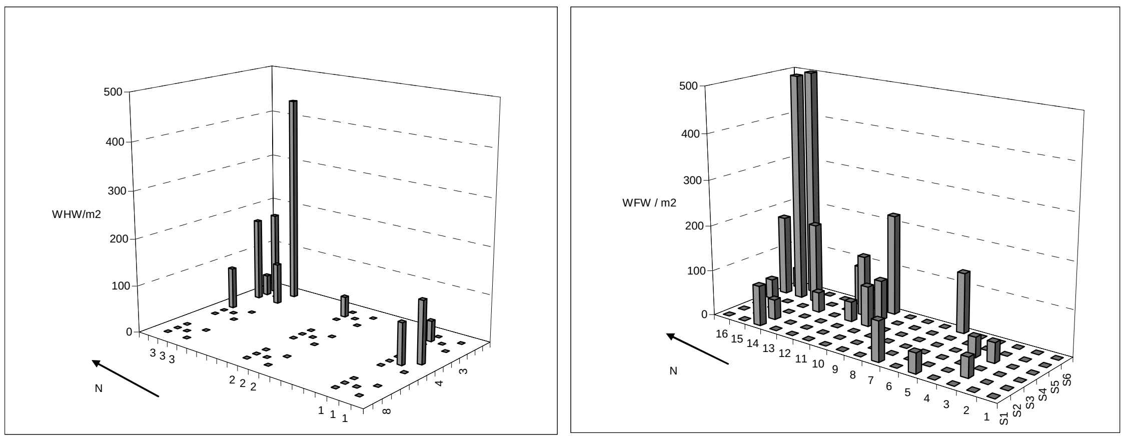

Fig. 7. The number of whitefringed weevil larvae found in two methods of soil sampling across a paddock.

The abundance of the main soil insects present, which includes brown- and white-headed weevil larvae and African black beetle for two sampling methods are given in Table 13. A brown headed weevil larva refers to apple weevil and garden weevil, with apple weevil being more commonly found in pasture areas in Manjimup/Pemberton. A white headed weevil larva refers to whitefringed weevil, small lucerne weevil and/or Fuller's rose weevil, with whitefringed weevil and small lucerne being more common in Manjimup/Pemberton pastures.

In general terms the abundance of these groups and insects were very similar for the two sampling methods. De Faveri *et al* (2002) undertook a more detailed examination of this data.

Table 13. The abundance of soil insects/m^2 measured using two sampling patterns – clustered and a regular grid. Stages of insects are indicated for weevils: as S = small, M = medium, L = large, P = pupa; for African black beetle (ABB): L1 = first instar larva, L2 = second instar larva, L3 = third instar larva; Tot = total of all stages for that insect or group. Brown-headed weevils refer to apple weevil and garden weevil; white-headed weevils refer to whitefringed weevil, small lucerne weevil and Fuller's rose weevil.

Method	**Brown Headed Weevil**					**White Headed Weevil**					**ABB**					
	S	M	L	P	**Tot**	S	M	L	P	**Tot**	L1	L2	L3	P	A	**Tot**
Cluster	5.8	0	0	0	**5.8**	24.7	0.8	0	0	**25.5**	0	0	0	0	0.8	**0.8**
Grid	8.3	0	0	0	**8.3**	32.4	1.4	0	0	**33.8**	0	0	0	0	0.5	**0.5**

In Western Australia, whitefringed weevil is a pest of potatoes primarily in the Manjimup/Pemberton region. For this region, results of the crop monitoring for abundance of larvae before planting and associated damage to tubers in untreated portions of paddocks is shown in Fig. 8a. The level of damage for densities of weevil larvae up to $10/m^2$ is shown in greater detail in Fig. 8b.

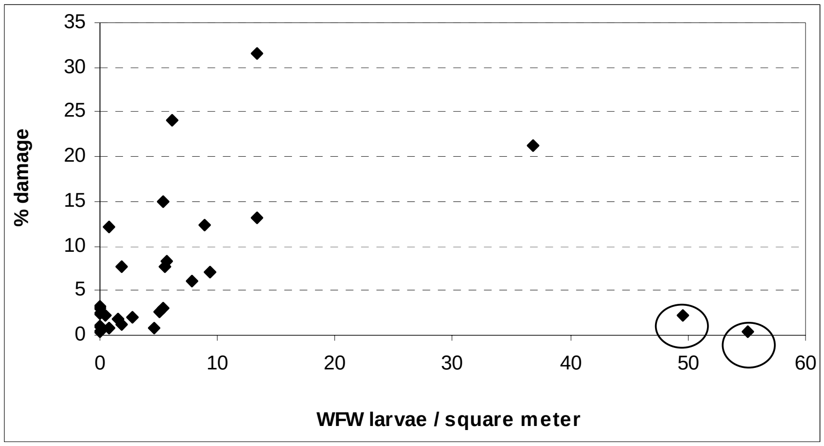

Fig. 8a. The level of damage to potato tubers in unprotected portions of potato paddocks and the abundance of whitefringed weevil larvae prior to planting in the Manjimup/Pemberton region of Western Australia. Data points circled indicate unexpectedly low levels of damage – see text for discussion.

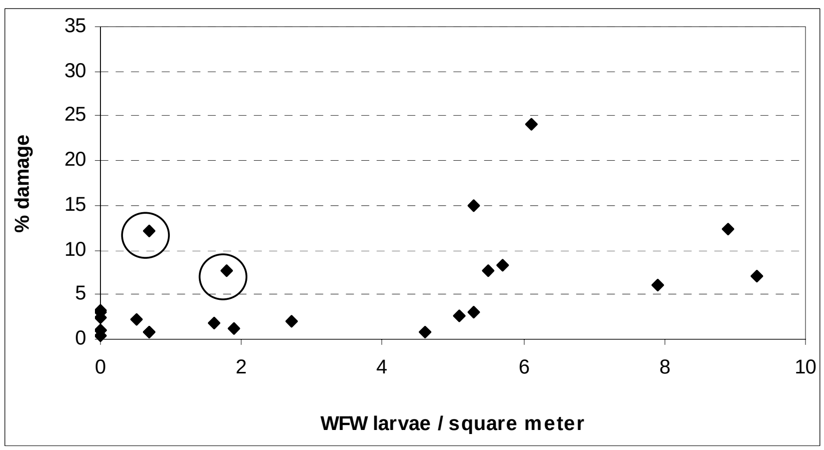

Fig. 8b. The level of damage to potato tubers in unprotected portions of potato paddocks and the abundance of whitefringed weevil larvae up to $10/m^2$, prior to planting in the Manjimup/Pemberton region of Western Australia. Data points circled indicate unexpectedly high levels of damage – see text for discussion.

In general terms, the damage to tubers from WFW larvae increases as pest abundance increases, but with some exceptions. There were two situations circled in Fig. 8a where the abundance of whitefringed weevil larvae was around $50/m^2$ but damage to tubers was less than 5%. In one of these crops, there was reason to believe that the insect larvae sampled were actually small lucerne weevil (*Atrichonotus taeniatulus*), SLW. This species is also capable of damaging potato tubers, but is much less important than WFW. Adults of SLW were subsequently observed in clover scattered in and on the edge of the area cropped to potatoes. Larvae of small lucerne weevil are difficult to distinguish from whitefringed weevil in the early stages of development. Both species are legless and have a white head capsule. It is only when larvae are longer than about 10 mm that they can be confidently identified as WFW. If the larvae were small lucerne weevil it is possible that they completed their development prior to tubers reaching any significant size. In this way damage to tubers would have been avoided. This crop was harvested on 20 March, which is only slightly late with respect to WFW, but for the smaller species SLW, the crop may be maturing after larval development has been completed.

In the second situation of high abundance of WFW larvae and an unexpected low damage level, the crop was sown in late spring. Based on the phenology of WFW in WA (Matthiessen, 1991), many of the larvae would have completed their development prior to tubers reaching a significant size. This crop was harvested on 23 April. A similar situation in relation to development rates and biology of WFW could arise in FNQ. For crops planted in April, high densities of WFW larvae found before planting may be inconsequential.

For weevil abundance up to 10/m^2 presented in Fig. 8b, two crops had damage levels above 5%. These results were unexpected based on the low level of pest numbers and indicate the possibility that more larvae were present than indicated when the soil sampling was undertaken to assess pest abundance.

The same data presented in Fig. 8a but with the abundance of larvae in ranges as shown, are given in Fig. 9. This indicates the variability in damage levels for a given range in WFW larval abundance. From the data gathered, it would be a low risk to not treat only when pest abundance was at or less than about 0.5 larvae/m^2. At densities in the higher series of ranges, the risk of high levels of damage becomes greater.

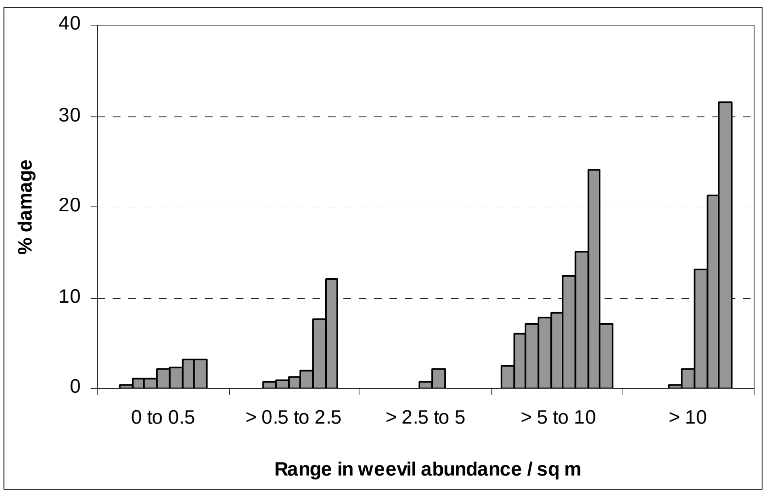

Fig. 9. The abundance of whitefringed weevil larvae as number/m^2 in ranges as shown and the level of damage to potato tubers in unprotected portions of potato paddocks in Manjimup/Pemberton, WA.

For the 51 paddocks sampled for WFW during this project in the Manjimup/Pemberton region, but not necessarily assessed for associated tuber damage, the abundance of larvae in the same ranges as in Fig. 9 is given in Fig. 10. Just over one-quarter of paddocks sampled were in what might be considered low risk paddocks for damage by WFW larvae, 0 to 0.5/m^2.

A comparison of the level of WFW damage to tubers in untreated areas to the level in insecticide treated areas in the same crop shows that treatment was usually successful in reducing damage (see Fig. 11). There were three exceptions to this.

One of these exceptions, where a damage level of 7.3% was recorded in the treated area, may be explained by the presence of more larvae than were actually found during the sampling. The second instance where the damage level in the treated portion was 12.3% was probably the result of very high weevil pest pressure - at 36.9 larvae/m^2. At this level of insect abundance, the insecticide control was possibly simply not good enough. At the third site, the higher than expected level of damage in the treated area was recorded where metham had been applied. Despite the relatively high abundance of weevil larvae at 13.4/m^2, a better level of control was expected. The reason for the apparent “control failure” of metham was unknown. The possibility that it was due to enhanced biodegradation was ruled out on the basis that the paddock had not been treated with metham before and soil types in this region are less prone to this phenomenon (Matthiessen *et al* , 2004) This level of poor control contrasted to the level of control achieved in the same paddock where a combination of chlorpyrifos and fipronil was applied (see Fig. 12).

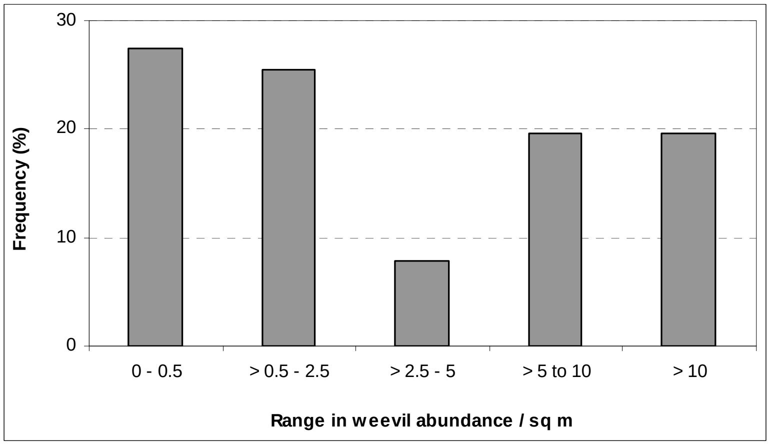

Fig. 10. The proportion of all paddocks sampled for whitefringed weevil larvae in Manjimup/Pemberton, WA for the ranges of weevil abundance shown on the figure.

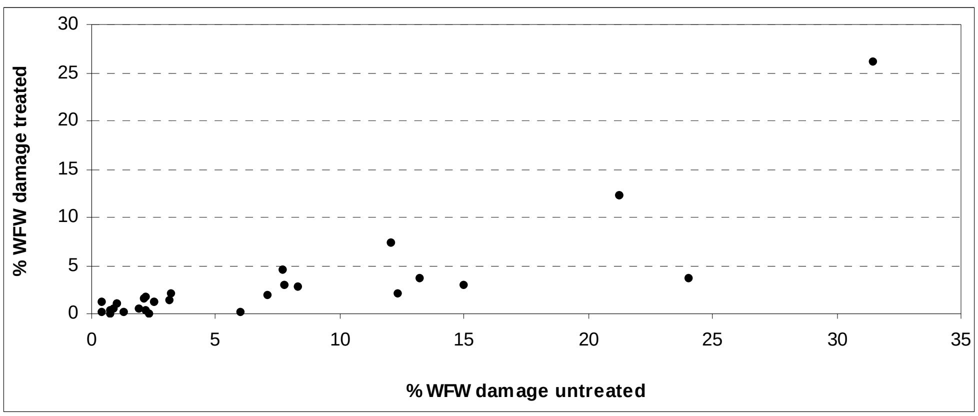

Fig. 11. The level of damage to potato tubers from larvae of whitefringed weevil in untreated portions of potato paddocks plotted against the level of damage in the same paddock where insecticide had been applied.

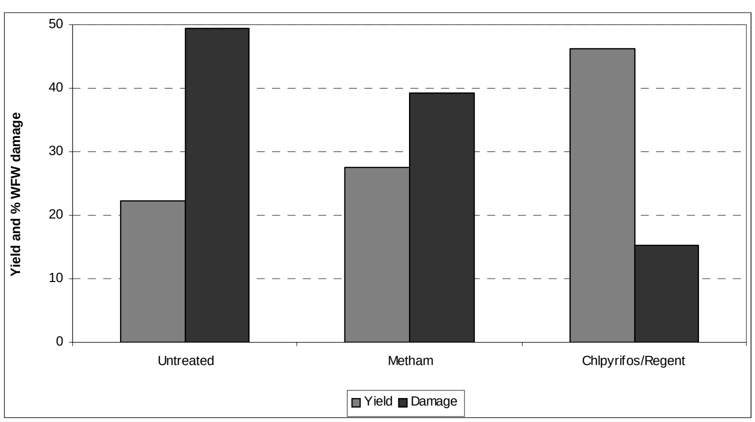

Fig. 12. Marketable yield (t/ha) and % tuber damage from whitefringed weevil larvae in sections of a potato paddock that were left untreated or treated with the pesticides Metham and a mixture of Chlorpyrifos and Regent.

Although paddock history was not included in any quantitative way in this study, the elimination of clover and broad-leaved plants in pasture paddocks has been practiced by one group of growers to reduce the abundance of whitefringed weevil. The objective has been to have paddocks based on oats and ryegrass. This has been attempted by the use of herbicides and sowing paddocks cropped to potatoes with oats immediately after harvest. This was done with a view to reducing the breeding potential of whitefringed weevil adults, which have highest fecundity when they have access to legumes (East, 1977). No data are available on the results of this management strategy, and the growers still apply soil pesticides for weevil control. However the growers suggest that damage to potato tubers by whitefringed weevil larvae has declined since they commenced this new strategy.

Discussion and Conclusions

The study on WFW in the Manjimup/Pemberton region had the objective of identifying risk of damage to potato crops based on the abundance of WFW larvae measured during pre-crop soil sampling. In general, the risk level advised to growers was confirmed by the level of subsequent crop damage to untreated portions of crops. The value of different levels of crop damage in relation to pesticide treatments to control soil pests is discussed in Appendix 3. For WFW, a damage level of around 5.6% when metham sodium is used for control was suggested.

In terms of providing advice to potato growers on the need to treat on the basis of soil sampling, the question arises as to what abundance level of WFW larvae can be used as a gauge. If soil sampling is undertaken by a consultant on behalf of the farmer, an estimate of the abundance level in terms of larvae per square metre will be available. The data obtained during this project for WA is summarised in Figs. 8a and b and 9. The information is by no means straightforward. As well as variability in damage levels across a range of pest numbers, there are notable exceptions to the relationship between the number of larvae and level of damage – at both extremes. There are instances of low pest densities and the threshhold being exceeded and high insect densities and the level for damage being below the threshhold. The reasons for these were speculated upon above.

The extremes of abundance of WFW larvae are clear (see Fig 9) – if no larvae are seen it is a reasonably safe decision that treatment is not required. For abundance levels above 5 per square metre, treatment is worthwhile. The difficulty occurs when intermediate densities are found, but also with the vagaries of WFW abundance and damage levels. Growers who have suffered complete crop failures as a result of WFW damage will tolerate fewer larvae than growers who have not had this experience. Situations have been experienced in WA where the presence of WFW at very low numbers resulted in damage levels above the threshhold.

In the process of deciding whether to treat a potato paddock, growers in WFW susceptible areas should take the obvious but not always practised step of checking the soil before planting. Control of WFW after planting is all but impossible. The grower has the choice of examining the paddock or seeking outside help, such as employing a consultant where available.

The level of WFW numbers at which the grower decides to apply pesticide will be based on his experience and discussion with the consultant, if applicable and local experienced government advisers. The actual numbers of WFW larvae per square metre can be a useful tool in deciding whether to treat but not the only factor to consider. As a guide, the information collected here suggests a threshhold level of between 0.5 and 1 WFW larva per square metre. This level is similar to the level of 1 WFW larva per square metre suggested from studies in Queensland. A different system of defining risk was used in the sampling for WFW in Victoria. Here the range of numbers of WFW larvae found was used to give advice to growers. This advice was accepted and confirmed in all but one instance.

Studies here confirmed the rigor of two soil sampling techniques to measure the abundance of WFW larvae – both systematic and clustered sampling gave similar results for a similar effort in sampling time required.

The effects of soil pesticides were examined and in general, acceptable control was achieved (see Fig. 11). However some inconsistent levels of control where metham sodium was used were recorded. No reasonable explanation for this apparent control failure was identified.

African black beetle

Results

In Western Australia, African black beetle (ABB) is a pest of potatoes primarily in the Busselton region, but can be important in crops in the Manjimup/Pemberton, Albany and Kirup regions. As the presence of ABB in the Manjimup/Pemberton region is often complicated by the combined presence of whitefringed weevil, data here are presented only for crops monitored in the Busselton region.

For this region, results of the crop monitoring for abundance of larval, pupal and adult stages of ABB before planting and associated damage to tubers in untreated portions of paddocks is shown in Fig. 13.

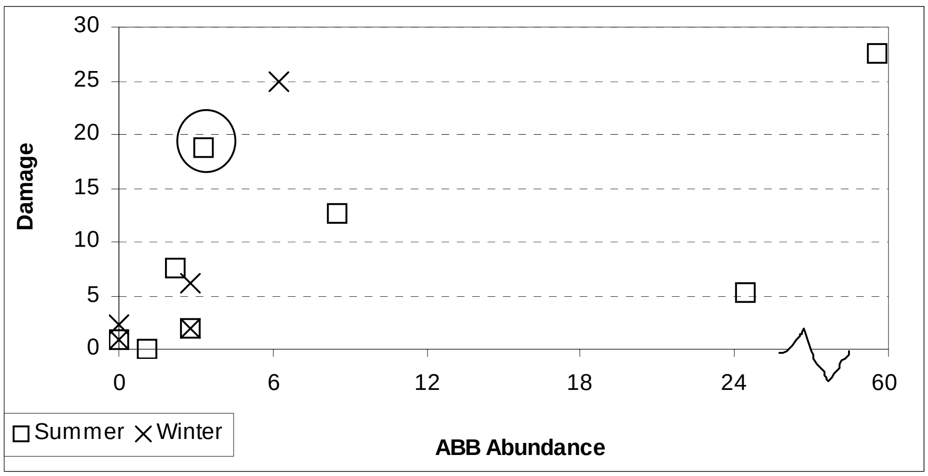

Fig. 13. The level of damage to potato tubers in unprotected portions of potato crops planted in summer and winter and the abundance of African black beetle/m^2 prior to planting in the Busselton region of Western Australia. For data point circled, see text for discussion.

Prior to this study, it had been accepted that where beetle populations were at 6 or more per square metre, it was worthwhile applying insecticide. The summer crop where the damage level was just under 20% (data point circled) was thought to have been subject to an invasion of an autumn flight of beetles. This aspect is discussed in more detail below. Therefore, the damage level associated with this crop is not considered relevant to the consideration of pre-crop sampling, risk of damage and need to apply a pre-plant application of insecticide. For the other crops in Fig. 13, the data suggest that a lower threshhold of around 3 beetles/m^2 may be a more relevant threshhold. More data are required to confirm this.

For the 57 paddocks sampled for the abundance of ABB before planting potato crops in the Busselton region, the frequency of crops for ranges in pest abundance is shown in Fig. 14. Of the areas sampled, just over half were at a level less than 3/m^2. The proportion of paddocks with a level of 6 beetles/m^2 or less, was just under 70%. This result indicates that many areas cropped to potatoes in the Busselton region may not require pre-plant insecticide treatment to protect them from ABB.

The relationship between the level of damage to potato tubers by ABB in untreated portions of potato paddocks and the level of damage in the same paddocks but where insecticide had been applied is shown in Fig. 15. The maximum level of damage in treated paddocks was around 5%. Compared to the high levels of damage in some paddocks where treatment had not been applied, the insecticide treatment successfully reduced damage in all potato crops where monitoring was undertaken. Of the 12 crops included in Fig. 15, 5 had damage levels

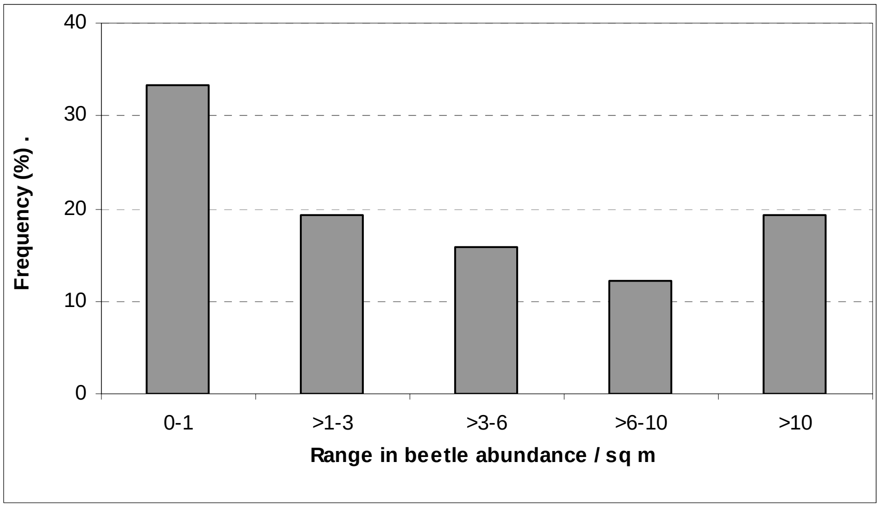

Fig. 14. The proportion of paddocks infested with African black beetle at the range of densities shown, for the Busselton region of WA in relation to potato cropping.

below 5% and it would have been questionable whether insecticide treatment was required in these paddocks.

The results of light trap catches over the three years of this project are shown in Fig. 16, with a maximum catch set at 200 for the purposes of presentation. In the first year, trapping was not commenced until April. Data from the light traps was made available to potato farmers in the Busselton region in WA to act as a warning of possible invasions of crops during their growing period.

Major flight activity of ABB adults usually occurs in autumn. The level of flight activity at other times of the year varies with weather conditions. Some major flights occurred in the spring of 2003/04 and late summer the same season. The level of flight activity varied over the region, emphasising the need to have more than one trap operating to measure possible local differences. These differences allow a better use of the traps as a warning tool such that localised differences in activity are measured.

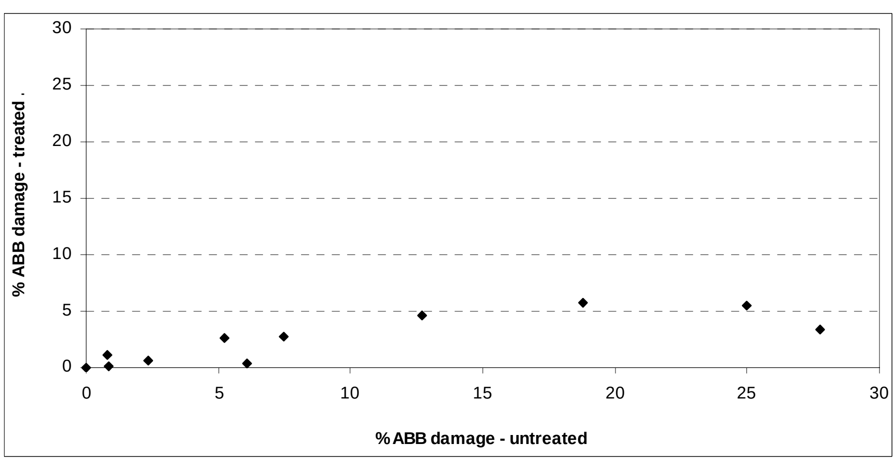

Fig. 15. The level of damage to potato tubers from African black beetle in untreated portions of potato paddocks plotted against the level of damage in the same paddock where insecticide had been applied.

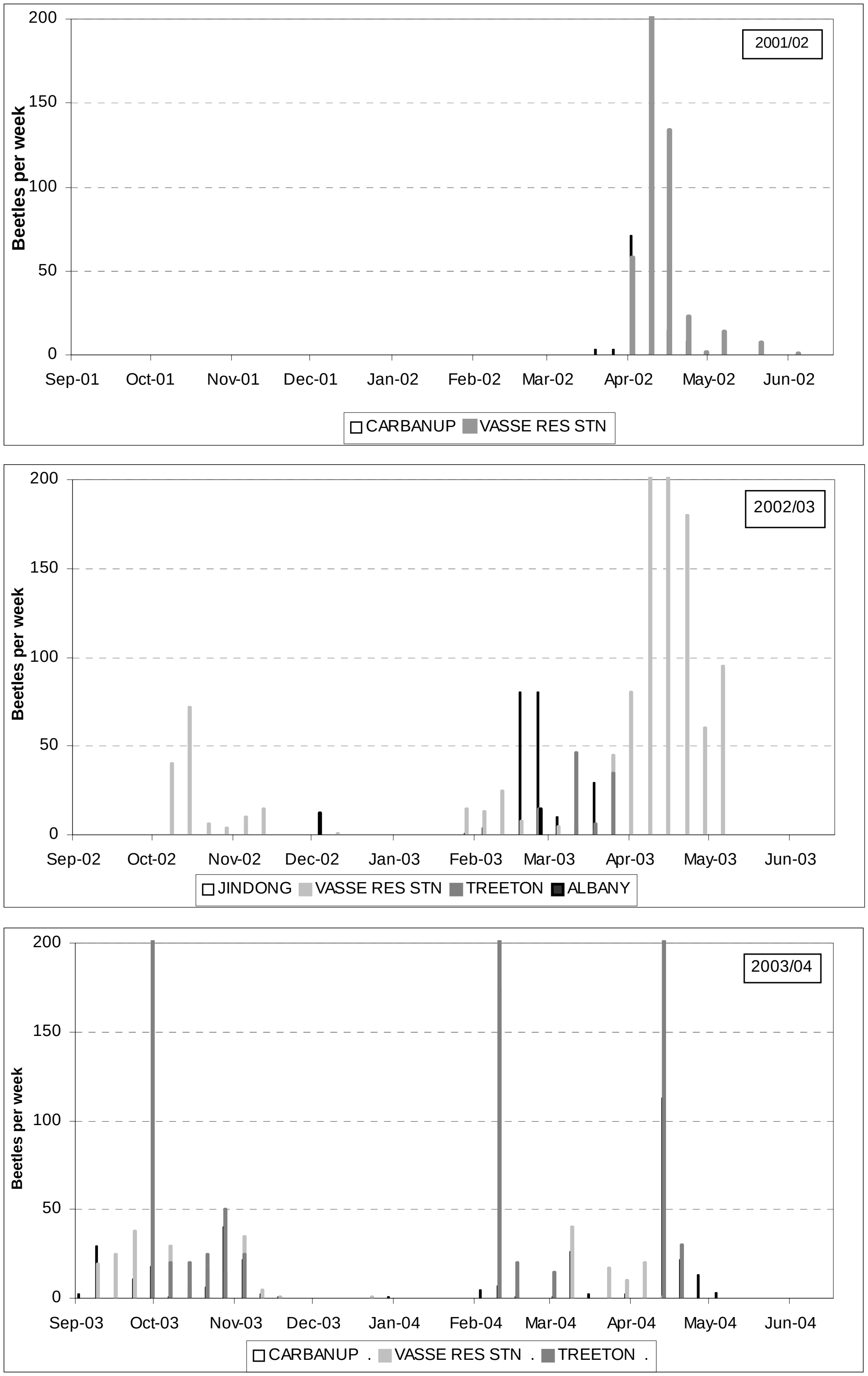

Fig. 16. Light trap catch data as number of African black beetle adults caught per week in the Busselton region of WA in three seasons as indicated on the graphs. In the first season, the traps were not run before April. One light trap was run in the Albany region in the 2002/03 season only. Data is presented with 200 beetles per week set as the maximum catch.

The effect of an immigrant flight of ABB adults on tuber damage in a summer planted Busselton crop was suspected to have been quantified in one of the crops monitored for risk of damage during the 2002/03 season. Pre-crop sampling showed the abundance of ABB to be 3.3/m^2. At this density, little damage to the crop was expected and the grower was asked to leave a portion of the crop untreated. The rest of the crop was treated with chlorpyrifos pre-plant and again in autumn after light traps recorded flights of beetles in the region in April 2002 (see Fig. 16). The untreated portion received none of these insecticide applications. At crop maturity, a damage level of 6% was recorded where the insecticide had been applied, but 19% of tubers were damaged in the untreated area. This difference was ascribed primarily to the occurrence of an immigration of adult ABB adults which caused more damage in the area that was not treated with insecticide.

Discussion and Conclusions

Pre-crop soil sampling to determine risk of damage to potato crops from ABB in general was considered reliable in terms of subsequent damage to potatoes (see Fig. 13). One notable exception was suggested to be due to immigrant adults later in the season.

From information on ABB abundance and the value of crop loss compared to cost of applying insecticide (see Appendix 2 for discussion), a suggested threshhold for applying insecticide to control ABB is between 2 and 3 ABB per square metre. When the frequency of areas sampled for ABB numbers that were below this threshhold (see Fig. 14), it is worthwhile for growers in the Busselton area to monitor their crop areas before planting. This would obviate the need for a pre-plant application of insecticide on around one-third of cropped areas.

Crop loss assessments showed chlorpyrifos insecticide provides reliable control of ABB (see Fig. 15). Despite the long-term use of this active ingredient since the time the organochlorine insecticides were withdrawn in the late 1980s, ABB resistance to this product does not appear to have developed.

On one occasion, the usefulness of monitoring ABB adult flight activity was measured. The use of light traps as a warning service to growers in ABB susceptible areas is commended.

Other soil pests

On one occasion in the Busselton region, a soil pest other than ABB was observed. At crop maturity, tubers were found to be damaged by a brown-headed weevil larva, as well as ABB (see Fig. 17). The damage level from ABB was reduced by the insecticide treatment over that recorded for the untreated area, however, tuber damage levels of 5% and 8% were recorded for treated and untreated areas respectively. At the time of soil sampling on 10 January 2002, no brown-headed weevil larvae were found. The soil in this crop was treated with metham sodium. This pesticide has no residual activity and it was suspected that adults of the brown-headed weevil invaded the crop and produced the larvae that were subsequently found damaging tubers at crop maturity on 25 July 2002.

This conclusion is also consistent with the fact that the treated area of the crop had a level of damage more similar to the untreated portion, indicating invasion occurred at the same time in both areas. The identity of the weevil was not confirmed, but based on observations on other crops in other years in this region, it is most likely that it was the garden weevil (*Phlyctinus callosus*). In the Manjimup/Pemberton region of WA, larvae of apple weevil (*Otiorhynchus cribricollis*) have been associated with damage to potato tubers but usually in late sown potatoes, which are harvested in late autumn. This species also occurs in the Busselton area, but has been associated with damage on fewer occasions than garden weevil there.

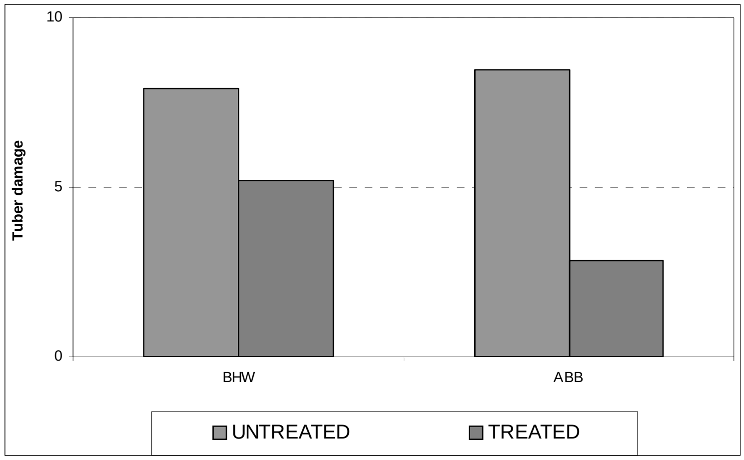

Fig. 17. Levels of tuber damage in a potato crop in the Busselton region caused by African black beetle and larvae of an unidentified species of brown-headed weevil suspected to be garden weevil in treated and untreated areas in the crop in 2002.

(B) INSECTICIDE USE: TRIALS AND SOME OBSERVATIONS

Whitefringed weevil

Materials & methods

Two trials on insecticide use against whitefringed weevil (WFW) are reported here. The first was an unreplicated plot demonstration to examine the efficacy of different rates and methods of application of the currently registered products chlorpyrifos and fipronil. The second was a fully replicated screening trial examining the efficacy of two new active ingredients, bifenthrin and cadusafos.

(a) Insecticide demonstration 2001/02

A paddock was selected for this experiment on the basis of presence of WFW larvae. A density of 36.9 larvae per square metre was determined on 3 September 2001. African black beetle adults were present, but at only 0.4 per square metre.

The range of insecticide treatments that was compared in the trial is listed in Table 14, with the treatment involving a mixture of insecticides being the commercial application to the crop.

Table 14. List of insecticide treatments compared for their efficacy against whitefringed weevil larvae in a potato crop in 2001/02.

Treatment	**Active ingredient**	**% AI**	**Rate product/ha**	**Application method**
*Untreated	-	-	-	
Lorsban 500 EC	chlorpyrifos	50	6 L/ha	in-furrow incorporated
*Regent 200 SC	fipronil	20	250 ml/ha	in-furrow incorporated
Regent 200 SC	fipronil	20	500 ml/ha	in-furrow incorporated
*Lorsban 500 EC	chlorpyrifos	50	6 L/ha	rotary tiller incorporated
*Regent 200 SC	fipronil	20	500 ml/ha	rotary tiller incorporated
*Regent 200 SC	fipronil	20	750 ml/ha	rotary tiller incorporated
*Lorsban 500 EC + Regent 200 SC	chlorpyrifos + fipronil	50 20	6 L/ha + 750 ml/ha	rotary tiller incorporated

*Samples of potato tubers from these treatments were obtained for insecticide residue testing.

All treatments were applied to single plots 55.5 m long and 6 m (8 rows) wide, giving an area per treatment of 0.0333 ha. An equivalent area in the adjacent commercial crop was marked out for comparison. The treatments applied by rotary tiller were incorporated broadscale before planting using a commercial rig at a spray solution of 250 L/ha. The in-furrow treatments were applied through a single nozzle per plant row set up on a commercial potato planter. The spray pattern from the flat fan nozzle was directed at the sett in the base of the planting hill and the sides of the planting furrow. A spray solution of 250 L/ha was applied.

Treatments were assessed on the basis of yield and insect damage to tubers at crop maturity. To assess this, tubers were harvested by hand with garden forks from 8 X 2 m crop row sampling units per plot.

Samples of potatoes from some treatments (see Table 14 for those included) were submitted to the Australian Government Analytical Laboratories to conduct insecticide residue tests on whole potatoes at crop maturity.

(b) Insecticide screening trial 2003/04

A paddock was selected for this experiment on the basis of presence of WFW larvae. A density of 8.9 larvae per square metre was determined on 17 September 2003. No ABB were found in this paddock during the sampling.

The range of insecticide treatments compared in the trial is listed in Table 15. These treatments include a comparison of the application of metham sodium by the farmer. Due to the phytotoxicity of metham sodium to potatoes it was applied about three weeks before planting. The other insecticides were incorporated in the soil within one week of planting potatoes.

Table 15. List of insecticide treatments compared for their efficacy against whitefringed weevil larvae in a potato crop in 2003/04.

Treatment	**Active ingredient**	**% AI**	**Rate product/ha**
Untreated	-	-	-
Metham Sodium	Metham present as the sodium salt	42.3	500L/ha
Regent 200 SC	fipronil	20	500ml/ha
Lorsban 500 EC	chlorpyrifos	50	6L/ha
Rugby 200CS	cadusaphos	20	2.5L/ha
Talstar 100 EC	bifenthrin	10	2.5L/ha

The metham sodium was incorporated in soil to a depth of approximately 25 cm using a blade plough. The other insecticides were incorporated in soil to a depth of approximately 20 cm using a rotary hoe with an insecticide boom placed immediately in front of the hoe. In this way insecticide was delivered through spray nozzles just in front of the rotary hoe and incorporated immediately. Insecticides were applied on 24 October 2003.

Apart from the metham sodium applied by the grower, the treatment layout to compare the efficacy of the insecticide treatments and an untreated control was a randomised complete block design. Because the metham sodium was applied by the farmer and because of the difficulty of using the blade plough in small plots, the comparison with this fumigant was made in large areas adjacent to the replicated plots for the other insecticides. The layout of the trial is shown in Figure 18.

The effectiveness of these treatments on controlling whitefringed weevil larvae was assessed on the basis of damage to tubers on crop maturity. For this 4 x 2 m lengths of row of potato crop were hand harvested by fork either within each plot or 20 such sampling units from adjacent areas in the commercial Metham treated area of potatoes. The tubers were examined individually and assessed as to whether they had whitefringed weevil damage, reject for other defects or marketable. Tubers were weighed after this assessment.

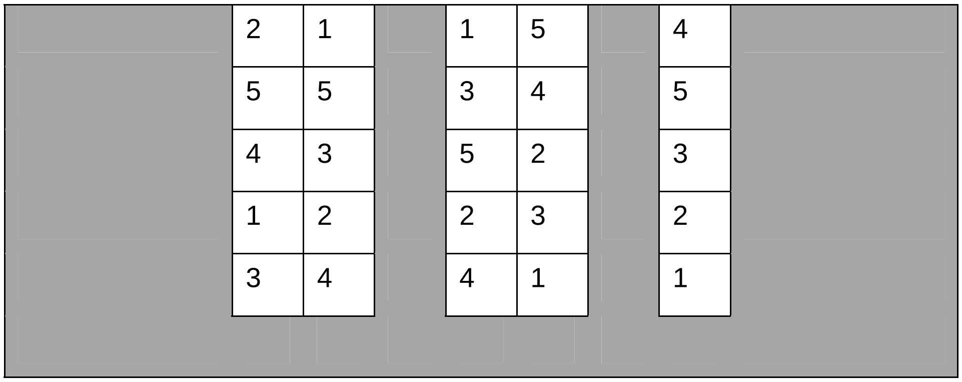

Fig. 18. Layout of insecticide treatments in a randomised complete block design to compare their efficacy against whitefringed weevil larvae in a potato crop. Treatments are 1 = untreated, 2 = Regent, 3 = Lorsban, 4 = Rugby and 5 = Talstar. The shaded area was treated with Metham Sodium. Except for the Metham treatment, each treatment plot was 6 m wide (8 rows) X 20 m long.

Results

(a) Insecticide demonstration 2001/02

The marketable yield of potatoes and average percentage of tubers damaged by whitefringed weevil larvae is shown in Table 16. There was no significant difference among the data on marketable yield. For damage by whitefringed weevil larvae, only the commercial treatment and the high rate of fipronil applied as a broadscale treatment were significantly lower than the untreated area.

Table 16. The marketable yield (kg/ha) and percentage tubers damaged by whitefringed weevil larvae in an insecticide trial, 2001/02.

Treatment	**% damage**	**Yield**
*Untreated	21.2	63.5
Regent 200 SC @ 250 ml/ha in-furrow	18.8	70.6
*Regent 200 SC @ 500 ml/ha in-furrow	17.5	68.9
*Regent 200 SC @ 500 ml/ha broadcast	15.3	69.0
*Lorsban 500 EC @ 6 L/ha broadcast	12.3	72.1
Lorsban 500 EC @ 6 L/ha in-furrow	12.2	77.9
*Regent 200 SC @ 750 ml/ha broadcast	9.1	81.6
*Commercial - Lorsban 500 EC @ 6 L/ha + Regent 200 SC @ 500 ml/ha broadcast	7.2	82.7
LSD (0.05)	9.4	ns

*Samples of potato tubers from these treatments were obtained for insecticide residue testing.

Results of testing whole potato tubers for residues of chlorpyrifos and fipronil from treatments indicated in Table 16 showed levels of <0.01 mg/kg, except for a chlorpyrifos residue level of 0.028 in the commercial treatment. This is below the MRL for chlorpyrifos of 0.05 mg/kg.

(b) Insecticide screening trial 2003/04

The average level of tuber damage from whitefringed weevil larvae for all insecticide treatments is shown in Figure 19. This data are also presented in Table 17 where levels of statistical significance for differences in the average levels of damage are included. For insect damage, the data required angular transformation. The data presented in Table 4 for insect damage are the transformed data and associated $LSD_{0.05}$ and with it, the backtransformed means. The highest level of damage was recorded in untreated plots, where the average level of damage was 10.3%. The lowest level of damage was recorded for potatoes treated with Metham. The levels of damage for Talstar and Regent were similar, but not significantly different to Metham treated potatoes. Plots treated with Lorsban suffered higher damage than Metham, Talstar and Regent, but this was not statistically significant. Damage levels of tubers in plots treated with Rugby were statistically the same as Lorsban, and also the same as untreated potatoes.

The yield of all potatoes and those assessed as marketable and reject is included in Table 17 also. There were no significant differences among treatments for any of these yield components.

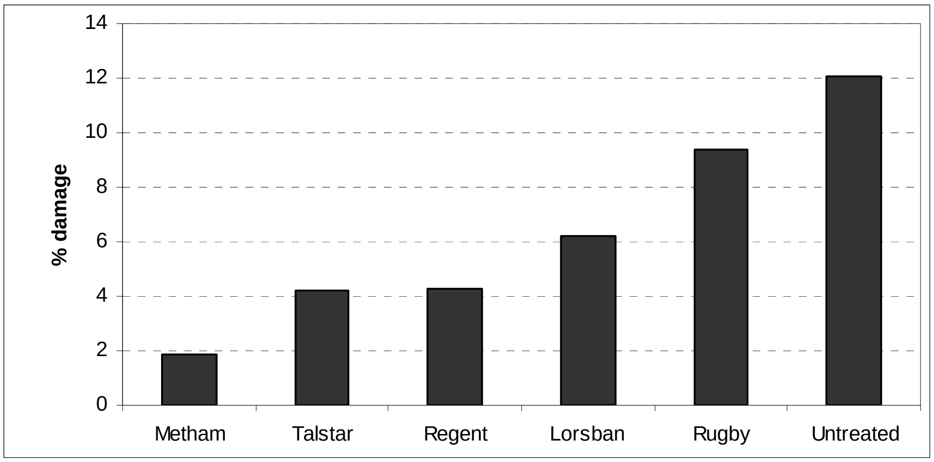

Fig. 19. Percent damaged potato tubers from a trial comparing the efficacy of a range of insecticides to control whitefringed weevil larvae.

Table 17. Total yield and classification of potato tubers to marketable, reject and damaged by whitefringed weevil larvae for a range of insecticide treatments assessed for their efficacy in protecting potato tubers from damage by whitefringed weevil larvae. Statistically significant differences were found only for insect damage.

Treatment	**Total Yield (t/ha)**	**Marketable Yield (t/ha)**	**Rejects (t/ha)**	[1] **% WFW larval damage**
Metham	68.7	62.7	6.6	4.7 (0.7)
Talstar	62.2	55.5	6.9	8.7 (2.3)
Regent	64.1	57.0	6.9	8.7 (2.3)
Lorsban	68.6	59.1	7.0	11.5 (4.0)
Rugby	69.2	58.2	6.5	15.5 (7.1)
Untreated	63.9	51.9	6.5	18.7 (10.3)
LSD (0.05)	**ns**	**ns**	**ns**	**7.4**

[1] % whitefringed weevil damage data was angular transformed; backtransformed data in brackets.

Discussion and Conclusions

(a) Insecticide demonstration 2001/02

This study was undertaken to assess the efficacy of different methods of application of the currently registered insecticides in protecting potatoes from attack by whitefringed weevil larvae. The different methods of application including a banded treatment would provide at least equivalent control to the current registered uses.

The treatment effects in this study were disappointing in that none of the treatments gave a high level of protection. This result was not assisted by the layout of the trial being unreplicated plots.

The in-furrow injection treatments did not give superior protection when compared to current commercial method of broad scale rotary hoe incorporation.

(b) Insecticide trial 2003/04

This study was undertaken to assess the efficacy of two soil active insecticides bifenthrin and cadusaphos, against the soil insect pests of potatoes whitefringed weevil and African black beetle. Such assessments require the presence of reasonable numbers of insects. Pre-crop soil sampling suggested the site chosen should have resulted in high levels of insect damage in untreated plots. This was achieved for whitefringed weevil with untreated plots at 12.1%.

For whitefringed weevil, bifenthrin demonstrated activity equivalent to the standard insecticides currently used for protection of potatoes from this pest. Cadusaphos was not effective.

Given the activity or suggested activity of bifenthrin, further work on this insecticide is justified. The availability of an insecticide that has apparent dual activity, including ABB (see below) provides potato growers with flexibility in control of soil pests in potatoes.

African black beetle

Material & methods

Two trials of soil-applied insecticides against African black beetle (ABB) are reported here. The first involved new insecticides and different methods of application, while the second trial reassessed the efficacy of bifenthrin and included the new insecticide cadusafos.

(a) ABB insecticide trial 2002.

A paddock was selected for this experiment on the basis of presence of ABB. A density of 61.7 ABB per square metre was determined on 23 January 2002, comprising an average of 1.1, 11.1 and 40.0 larval instars I, II, and III, respectively, 8.9 pupae and 0.6 adults.

The range of insecticide treatments that was compared in the trial is listed in Table 18. The treatment layout to compare the efficacy of the insecticide treatments was as eight adjacent unreplicated plots, with each plot being 15 m wide (20 potato rows) and 20 m long. The area was on the end of a commercial crop of potatoes.

The insecticides were soil incorporated one week before planting. They were incorporated to a depth of approximately 20 cm using a rotary hoe with an insecticide boom placed immediately in front of the hoe. The insecticide was delivered through spray nozzles just in front of the rotary hoe and incorporated immediately. The banded treatments were applied during planting of the potatoes on January 2004.

The effectiveness of these treatments on controlling ABB was assessed on the basis of abundance of dead adult beetles and damage to stems during crop growth, and damage to tubers at crop maturity. For stem damage, five by 5 m crop row were examined in each plot on 14 March 2002. Insect damage at crop maturity was assessed by examining tubers hand harvested by fork from 9 x 2 m lengths of row within each plot on 20 May 2002. The tubers were examined individually and assessed as to whether they had ABB damage, rejected for defects or marketable. Tubers were weighed after this assessment.

Samples of potatoes from each treatment and the adjacent commercial potato crop were submitted to the WA Chemistry Centre to conduct insecticide residue tests on whole potatoes at the time of the potatoes reaching maturity.

Table 18. List of insecticide treatments compared for their efficacy against African black beetle in a potato crop, 2002.

Treatment	Active ingredient	% AI	* Rate product/ha
Untreated	-	-	- RH
Lorsban 500 EC	chlorpyrifos	50	6 L/ha RH
Talstar 100 EC	bifenthrin	10	2 L/ha RH
Bulldock 25 EC	cyfluthrin	25	4 L/ha RH
suSCon Indigo 10G	chlorpyrifos	10	30 kg/ha B
suSCon Indigo 10G	chlorpyrifos	10	15 kg/ha B
Lorsban 500 EC	chlorpyrifos	50	6 L/ha B
Lorsban 500 EC	chlorpyrifos	50	3 L/ha B

* RH = pre-plant rotary hoe incorporated or B = banded into the plant row during planting.

(b) ABB insecticide trial 2003/04

A paddock was selected for this experiment on the basis of presence of ABB. A density of 24.4 larvae per square metre was determined on 16 December 2003, comprising an average of 3.1, 12.0 and 9.3 instar I, II and III respectively. No ABB pupae or adults were found in this paddock during the sampling.

The range of insecticide treatments that was compared in the trial is listed in Table 19. The insecticides were soil incorporated on 5 February 2004, one week before planting. They were incorporated to a depth of approximately 20 cm using a rotary hoe with an insecticide boom placed immediately in front of the hoe. The insecticide was delivered through spray nozzles just in front of the rotary hoe and incorporated immediately.

Table 19. List of insecticide treatments compared for their efficacy against African black beetle in a potato crop in 2003/04.

Treatment	Active ingredient	% AI	Rate product/ha
Untreated	-	-	-
Lorsban 500 EC	chlorpyrifos	50	6 L/ha
Rugby 200 CS	cadusaphos	20	2.5 L/ha
Talstar 100 EC	bifenthrin	10	2.5 L/ha

The treatment layout to compare the efficacy of the insecticide treatments and an untreated control was a randomised complete block design with 5 replications.

The effectiveness of these treatments on controlling ABB was assessed on the basis of damage to stems during crop growth and tubers at crop maturity. For stem damage, two by 5 m crop rows were examined in each plot on 17 March 2004. Total stems and the number damaged by ABB were recorded. Insect damage at crop maturity was assessed by examining tubers hand harvested by fork from 5 x 3 m lengths of row within each plot on 15 June 2004. The tubers were examined individually and assessed as to whether they had ABB damage, rejected for defects or marketable. Tubers were weighed after this assessment.

Results

(a) ABB insecticide trial 2002

The average level of stem damage caused by ABB adult feeding and numbers of dead beetles in plots are shown in Fig. 20. The highest number of stems was recorded for plots treated with chlorpyrifos EC incorporated pre-plant. These plots also had the lowest percentage of stems damaged by ABB but the lowest number of dead adults. The highest proportion of stems damaged was in the plots treated with suSCon Indigo but these plots also had the highest numbers of dead beetles.

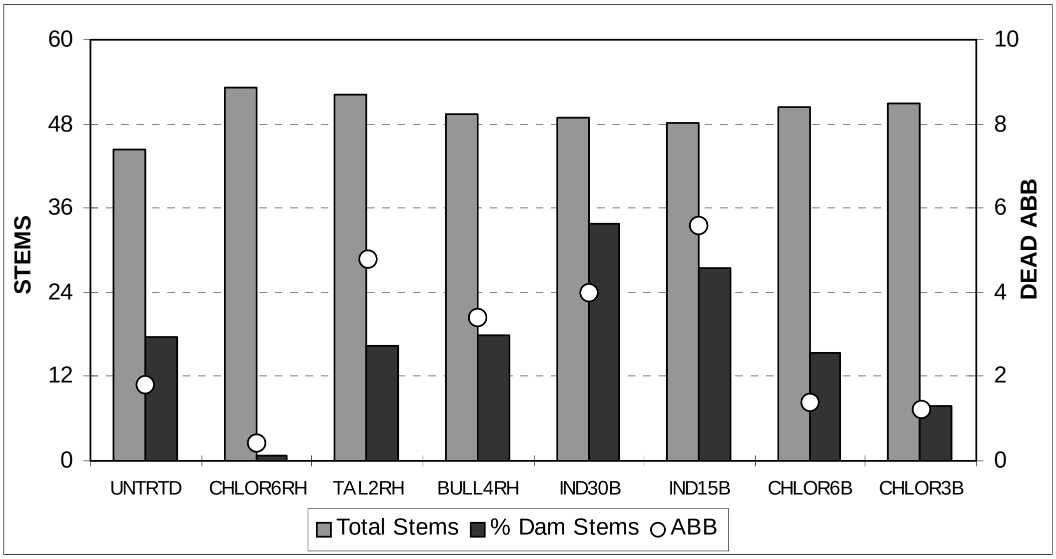

Fig. 20. The average total number of stems per 5 m crop row, percentage of stems damaged by African black beetle and number of dead beetles adults per 5 m crop row in plots treated with different insecticides and methods of application.

The average level of tuber damage from ABB for all insecticide treatments at crop maturity is shown in Figure 21. The lowest levels of tuber damage and highest yields were in plots treated with chlorpyrifos pre-plant both in the demonstration area and in the adjacent commercial area and in the plot treated with bifenthrin.

Banding chlorpyrifos EC into the potato hill did not protect the potatoes as well as the broadcast incorporation of the product prior to planting. At the higher rate of banding, the percentage of tubers damaged was less than that for the lower rate and the yield of marketable potatoes was greater.

The highest levels of tuber damage were in plots treated with the lower rate of suSCon Indigo and the untreated plot. The level of damage to tubers for the higher rate of banding suSCon Indigo and cyfluthrin was intermediate but did not appear to provide good protection of the potatoes from ABB.

The results of the insecticide residue testing by the WA Chemistry Centre are given in Table 20. The MRL for chlorpyrifos for potatoes is 0.05 mg/kg. None of the treatments involving chlorpyrifos exceeded this level. There is no MRL for bifenthrin or cyfluthrin in potatoes. For comparative purposes the MRL currently set for sweet potatoes, which is in the same food group as potatoes is 0.05 mg/kg, the limit of analytical quantitation. This level was not exceeded in this study. For cyfluthrin, the lowest level currently set for any commodity is 0.01 mg/kg, also the limit of analytical quantitation for this insecticide. This level was not exceeded in this study.

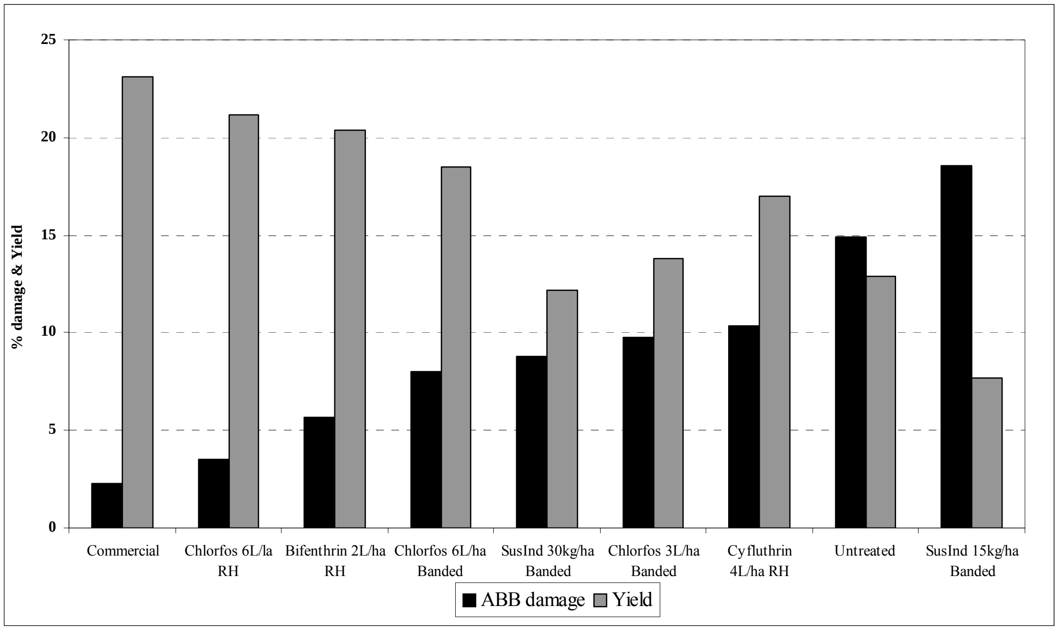

Fig. 21. The average level of tuber damage by African black beetle in plots treated with different insecticides as a percentage by weight of the total harvest and the marketable yield (t/ha) of potatoes in each plot.

Table 20. The level of insecticide residue in mg/kg for whole potatoes from each of the insecticide treatments in the insecticide trial.

Treatment	chlorpyrifos	bifenthrin	cyfluthrin
Untreated	0.011	0.013	<0.01
chlorpyrifos 500 EC @ 6L/ha broadcast	0.023	<0.01	<0.01
Talstar 100 EC @ 2L/ha broadcast	<0.005	<0.01	<0.01
Bulldock 25 EC @ 4L/ha broadcast	<0.005	<0.01	<0.01
suSCon Indigo 10G @ 30kg/ha banded	0.005	<0.01	<0.01
suSCon Indigo 10G @ 15kg/ha banded	0.006	<0.01	<0.01
chlorpyrifos 500 EC @ 6L/ha banded	0.022	<0.01	<0.01
chlorpyrifos 500 EC @ 3L/ha banded	<0.005	<0.01	<0.01
Commercial crop: chlorpyrifos 500 EC @ 6L/ha broadcast	0.012	<0.01	<0.01

(b) ABB insecticide trial 2003/04

The average level of stem damage caused by ABB adult feeding on stems is shown in Fig. 22. The highest number of stems per 5 m crop was recorded for plots treated with Lorsban. These plots also had the lowest percentage of stems damaged by ABB. A similar proportion of stems damaged by ABB was recorded for plots treated with Talstar. For plots treated with Rugby and untreated plots, a higher level of stem damage was recorded.

These data were subjected to ANOVA (see Table 21). The analysis of these data showed a significant treatment effect - there was a significantly greater density of stems in chlorpyrifos treated plots compared to Talstar and untreated plots. However, in neither case was the difference very large. For the proportion of stems damaged, an ANOVA showed no significant treatment effect.

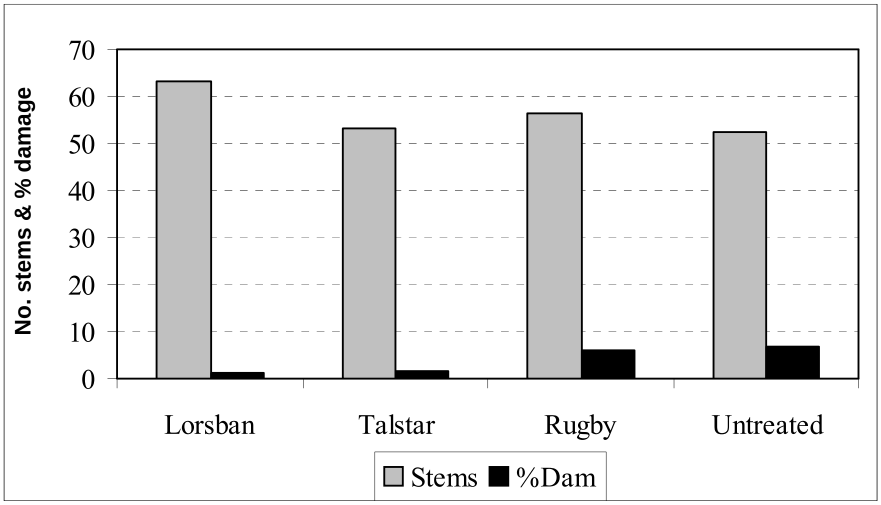

Fig. 22. The average total number of stems per 5m crop row and percentage of stems damaged by African black beetle in plots treated with different insecticides.

Table 21. The average total number of stems and proportion of stems damaged by African black beetle in plots treated with different insecticides and LSD values from an analysis of variance.

Treatment	**Total Stems (no./5m row)**	[1] **ABB stem damage (%)**
Lorsban	63.4	4.4 (0.59)
Talstar	53.3	3.7 (0.42)
Rugby	56.3	12.8 (4.91)
Untreated	52.6	12.3 (4.54)
LSD (0.05)	**10.0**	**ns**

[1] Data on African black beetle damage was transformed to arcsin values; backtransformed data in brackets.

The average level of tuber damage from ABB for all insecticide treatments is shown in Figure 23. This data is also presented in Table 22 together with data on yield components. Statistical analyses of these data showed no differences between any of these crop components and insecticide treatments. For insect damage, the data required angular transformation. The data presented in Table 9 for insect damage is the transformed data and associated $LSD_{0.05}$, and with it, the backtransformed means. The highest level of damage was recorded in untreated plots at 4.4%. The lowest level of damage was recorded for potatoes treated with Talstar at 2.3%. The level of damage for Lorsban was similar, but not significantly different to Talstar treated potatoes. Plots treated with Rugby suffered higher levels of damage than Lorsban and Talstar. Levels of damage from the insecticide treated plots were not significantly different to that for untreated plots.

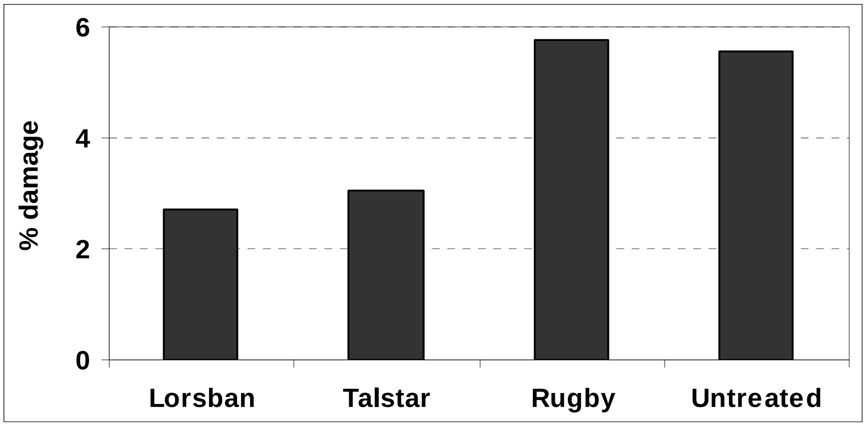

Fig. 23. The average level of tuber damage by African black beetle in plots treated with different insecticides.

Table 22. Total yield and classification of potato tubers to marketable, reject and damaged by African black beetle for a range of insecticide treatments assessed for their efficacy in protecting potato tubers from damage by African black beetle. LSD $_{(0.05)}$ is shown for each category. No statistically different differences were found.

Treatment	Total Yield (t/ha)	Marketable Yield (t/ha)	Rejects (t/ha)	[1] ABB damage
Lorsban	42.6	38.3	3.1	0.52 (2.3)
Talstar	42.7	38.5	2.9	0.51 (2.2)
Rugby	40.5	35.2	3.0	0.77 (4.8)
Untreated	40.5	35.5	2.8	0.74 (4.4)
LSD (0.05)	**ns**	**ns**	**ns**	**ns**

[1] African black beetle damage was transformed to log(% damage + 1); backtransformed data in brackets.

Discussion and Conclusions

(a) Insecticide demonstrations 2002.

This study was undertaken to assess the efficacy of a range of insecticides and different methods of application in protecting summer-sown potatoes from attack by the soil pest African black beetle. The study had the objectives of determining whether more strategic applications of chlorpyrifos EC as a banded treatment would provide at least equivalent control to the current registered use for this insecticide. Another objective was to determine whether a slow release formulation of chlorpyrifos could give protection to the crop for its entire duration, including protection from immigrant flying beetles. Two other active ingredients not currently registered for use against ABB but which were considered to be possible supplements to chlorpyrifos were also included in the study to assess their efficacy.

Any conclusions drawn from this study must be tempered by the fact that data are drawn from unreplicated plots.

The results of this study indicate that bifenthrin has activity against African black beetle and is worthy of further consideration. No other treatment performed as well as the commercial standard of a pre-plant broadscale incorporation of chlorpyrifos EC.

The banded treatments of chlorpyrifos EC were included to determine whether this more strategic application of insecticide would provide control of a resident population of beetles, at least equivalent to the pre-plant broadacre application. This application method did not provide acceptable protection. This is in contrast to earlier trials that did demonstrate that this method could provide control.

The reason for including the slow release chlorpyrifos product suSCon Indigo was to determine whether season long protection of potatoes from damage by African black beetle were possible with the banding of this product near the top of the potato hill. The aim was to protect the crop in two ways – protect emerging stems from a resident population of beetles and to protect forming tubers later from potential immigrant beetles that can fly into summer planted crops in autumn. At this time, around April, any pre-plant applied chlorpyrifos EC would be at a concentration too low to kill beetles. From the results in this preliminary study, this product gave insufficient protection even from attack by the resident ABB population.

The alternative pre-plant applied insecticide cyfluthrin gave inadequate control. This is despite the fact that this insecticide is registered for control of African black beetle in turf at around one-fifth the rate of active ingredient used in this study.

Analysis of potato tubers from each treatment and the adjacent commercial crop of potatoes for insecticide residues indicated that violative insecticide residue levels would not be an issue should any of these insecticide treatments be considered viable from an efficacy point of view.

(b) Insecticide trial 2004.

This study was undertaken to assess the efficacy of two soil active insecticides bifenthrin and cadusaphos, against the soil insect pests of potatoes whitefringed weevil and African black beetle. Such assessments require the presence of reasonable numbers of insects. Pre-crop soil sampling suggested sites chosen for both pests should have resulted in high levels of insect damage in untreated plots. For African black beetle, the level of tuber damage in untreated plots was only 5.6%. At this level, which is considered to be near the economic threshhold for this soil pest, the rigor of the efficacy trial is questionable.

For African black beetle, despite the lower level of damage in untreated plots, the application of bifenthrin resulted in a stem and tuber damage level equivalent to the current commercial standard. Cadusaphos use did not reduce stem or tuber damage over untreated plots.

Given the activity or suggested activity of bifenthrin over two important soil insect pests of potatoes, further work on this insecticide is justified. The availability of an insecticide that has apparent dual activity provides potato growers with flexibility in control of soil pests in potatoes. Bifenthrin is registered for use against sugar cane wireworm and false wireworm. Given that pests in these groups of beetles are also pests of potatoes in Australia, there is further incentive to consider more investigations on this insecticide for use in potato crops.

Telone demonstrations

Methods

Pre crop soil sampling for insect pests identified two potato crop areas suitable for comparing the pesticides. The land had been prepared as per usual district practice for application of metham sodium, which included cultivation and rotary hoeing. A contractor applied Telone @ 150 kg/ha and Telone C35 @ 300 kg/ha to strips across the paddocks. On one farm the strips were approximately 5.4 m wide, which was equivalent to two passes of the incorporation rig. On the second farm, only one pass of the rig was made. The individual farmers applied metham sodium @ 500 L/ha and this was applied across the rest of the paddock, except for an untreated strip equivalent in size to the Telone and Telone C35 strips. In this way four adjacent equal sized strips were prepared for the comparisons.

Soil sampling was undertaken after application and before planting to assess insect abundance in each of the four areas, which included the untreated strip.

Just before commercial harvest on each farm, ten 2 m crop row plots were hand dug in each treatment strip and assessed for insect damage and yield.

Fifty tubers were selected randomly from each of 5 (property 1) and 10 (property 2) 'replicate' sites per treatment. Tubers were assessed for all visible surface diseases in the laboratory immediately after harvest.

Results

Property 1

The abundance of soil insects was moderate at the time of the pre-crop sample, but declined to such low levels later as to not be able to demonstrate any treatment effects. This was evident in tuber assessment where around 4% tuber damage from insects was noted in potatoes from the untreated strip. There were minor differences in marketable yield (see Fig. 24).

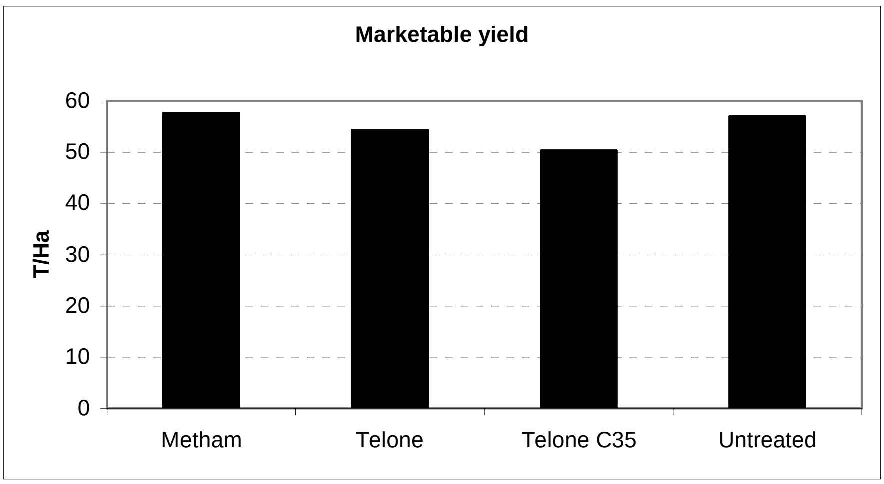

Fig. 24. Marketable yield estimated from each of the treatment areas in the potato crop on Property 1.

The incidence of only the most prevalent disease on property 1 is shown in Fig. 25. This disease was black dot. The disease was present at roughly equivalent levels in potatoes in all four treatment areas. The inference is that the disease may have been present on the seed pieces so that any effect the pesticides may have had on a soil borne source would have been small by comparison.

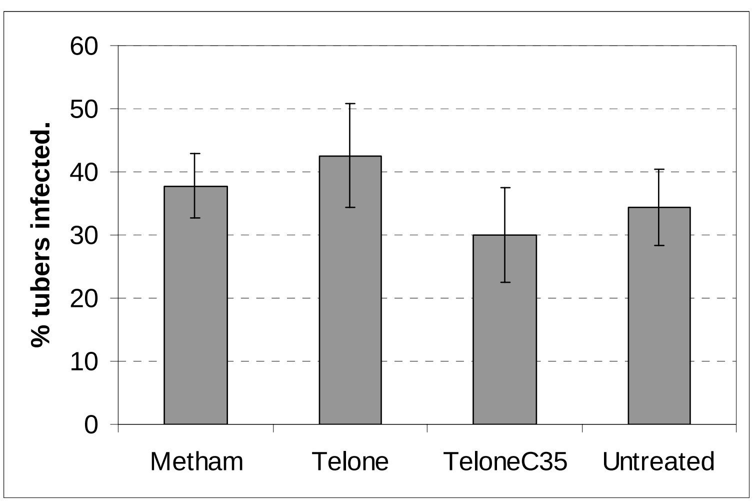

Fig 25. The incidence of black dot on potatoes on Property 1 in relation to different pesticide treatments.

Property 2

The abundance of whitefringed weevil larvae and African black beetle on Property 2 before and after application of the pesticides are shown in Tables 23 and 24, respectively.

The application of the treatments appeared to have no effect on the abundance of weevil larvae (see Table 1). Considering the differences in damage by whitefringed weevil larvae to tubers at crop maturity where the untreated strip had the greatest level of damage (see below), the soil sampling result could have been a reflection of an insufficient number of sampling units being examined. The second (post treatment) soil sample was based on only 15 spade sample units, whereas the pretreatment assessment was based on 100 units.

Table 23. Density of whitefringed weevil larvae per square metre from soil sampling before and after treatment with pesticides in an area to be sown to potatoes. The pre-treatment sample was an average across the paddock, while the post treatment sample was from treatment strips.

Treatment	Pre treatment 22 Aug 2002	Post treatment 8 Oct 2002
Untreated	6	3
Metham Sodium		3
Telone		3
Telone C35		18

All pesticide treatments reduced the abundance of African black beetle (see Table 24).

Results of the assessment of tubers for insect damage and yield aspects at crop maturity are shown in Figs. 26 to 30.

Whitefringed weevil larvae caused more damage than African black beetle. The highest level of insect damage was in the untreated strip, where whitefringed weevil caused around 8% damage and African black beetle 1%.

Marketable yield was lowest in the untreated strip, with the main reason being the level of insect damage (see Figs. 26 and 27). Likewise, total yield was lowest in the untreated strip (Fig. 28), but the level of reject tubers was roughly equivalent across the treatment strips (Fig. 29).

Table 24. Density of African black beetle from soil sampling before and after treatment with pesticides in an area to be sown to potatoes. The pre-treatment sample was an average across the paddock, while the post treatment sample was from treatment strips.

Treatment	Pre treatment 22 Aug 2002	Post treatment 8 Oct 2002
Untreated	7	9
Metham Sodium		0
Telone		0
Telone C35		0

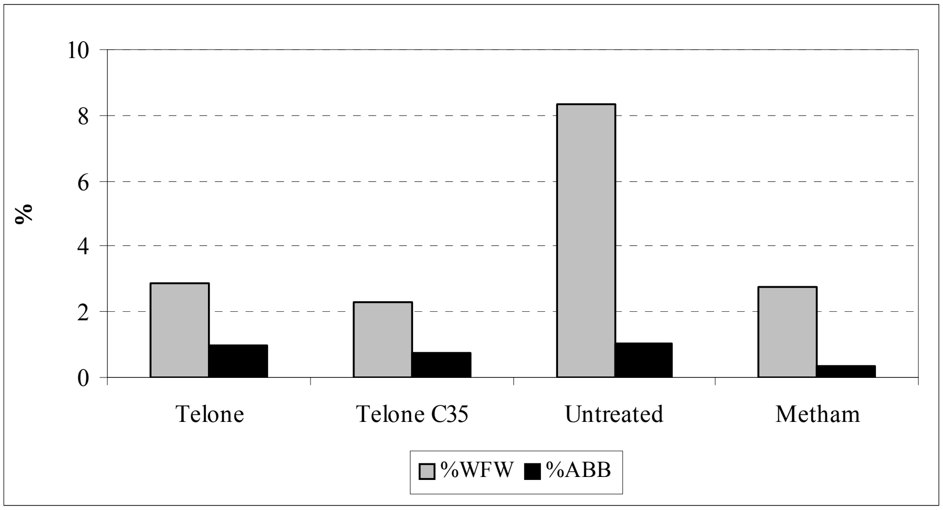

Fig. 26. The level of damage to potato tubers caused by whitefringed weevil larvae and African black beetle.

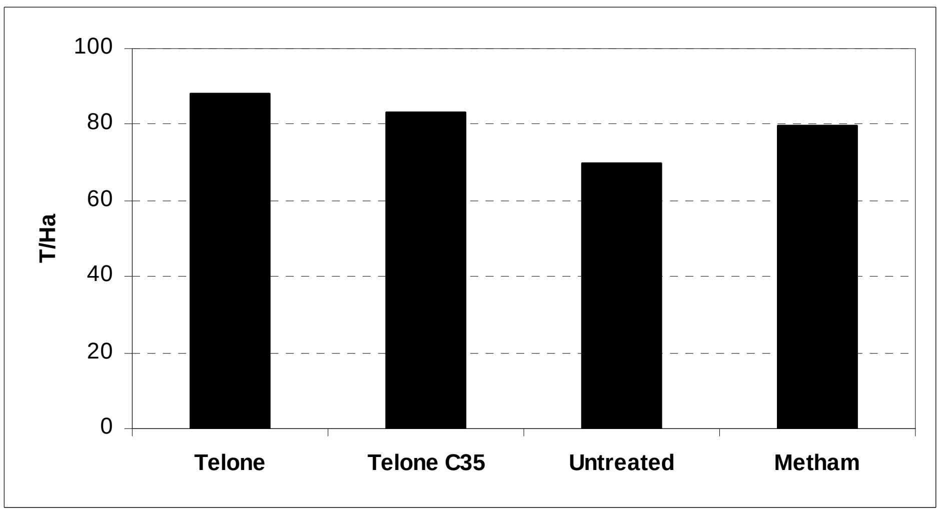

Fig. 27. The marketable yield of potatoes from different pesticide treatments.

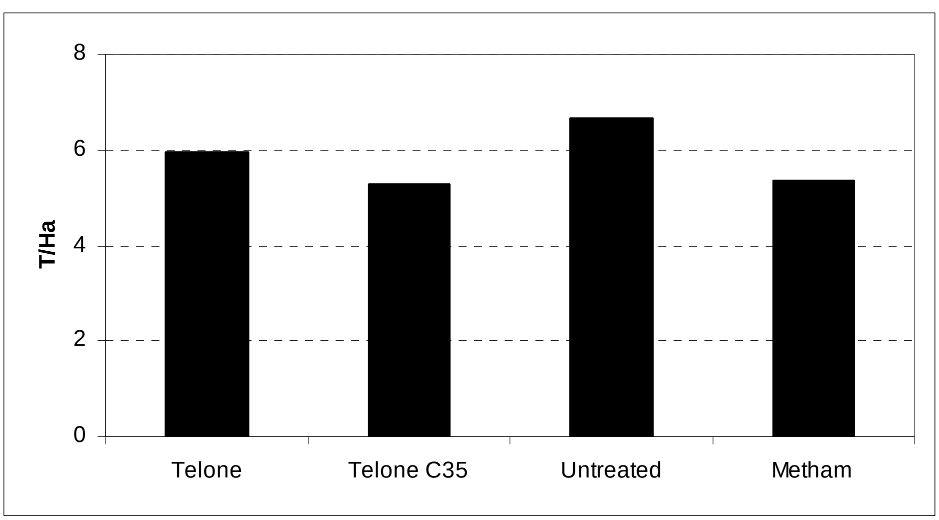

Fig. 28. The total yield of potatoes from different pesticide treatments.

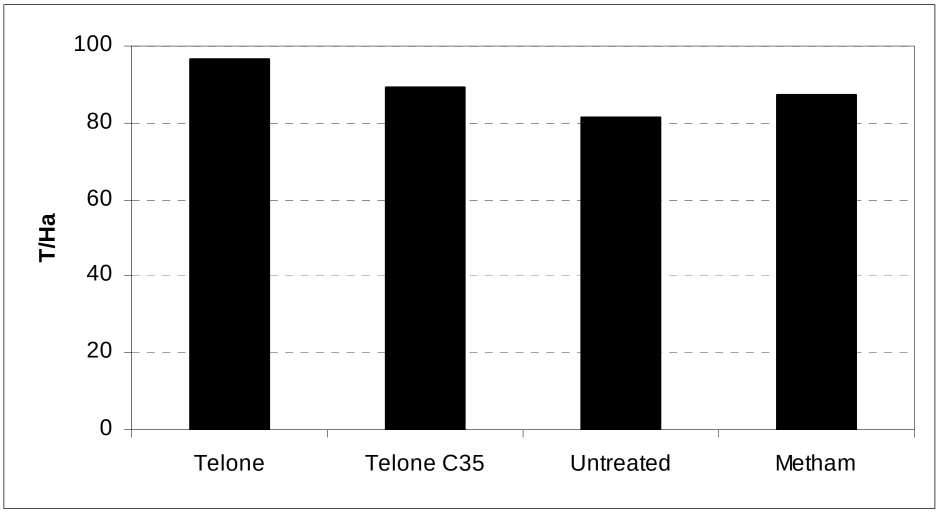

Fig. 29. The yield of reject potatoes from different pesticide treatments.

The incidence of only the most prevalent disease on property 2 is shown in Fig. 30. This was rhizoctonia. The disease was more prevalent on the Metham Sodium and Telone C35 treated plots. The inference is that these pesticides may have had an effect on a soil borne agent (or agents) that may be antagonistic to the rhizoctonia present on the seed used on this property. The possible reduction in the variety of microfauna may have allowed a greater level of spread of seed borne rhizoctonia to developing new tubers in areas treated with Telone C35 and metham sodium.

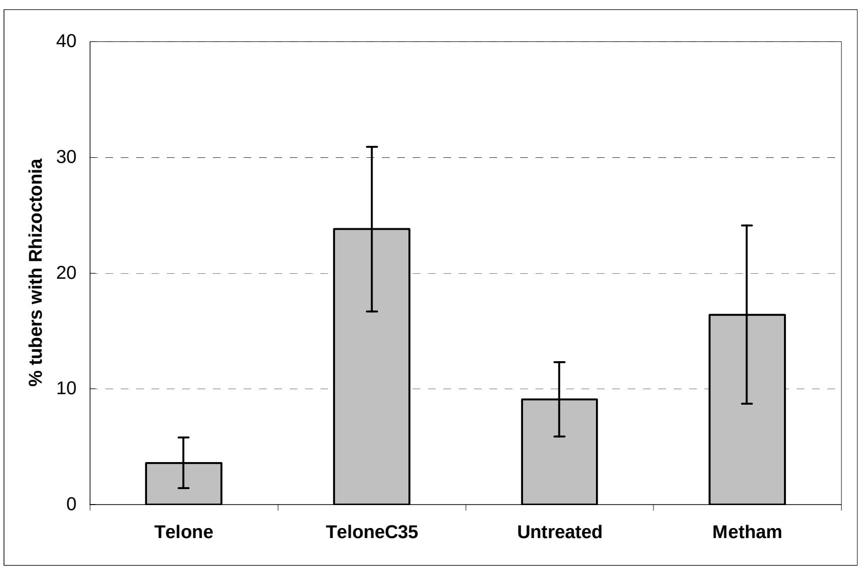

Fig. 30. The incidence of rhizoctonia on potato tubers on Property 2 where the soil had been untreated or treated with three different pesticides.

Discussion

The results reported here must be regarded as preliminary because unreplicated treatment strips were used. Nevertheless, the indications are that the new pesticides Telone and Telone C35 have some activity against soil borne insect pests of potatoes.

The role of these pesticides in protecting crops from soil borne diseases is unclear. The apparent exacerbation of rhizoctonia by Telone C35 and Metham Sodium is cause for concern and if this result is repeated in subsequent investigations, careful consideration will be required where these pesticides may be used.

Metham sodium yield boost

While assessing the damage caused by whitefringed weevil and African black beetle in potato crops, a surprising result relating to the use of metham sodium as a pre-plant soil treatment was recorded. Where metham had been applied, the marketable yield of potatoes was considerably higher than in untreated areas in the same paddock. This effect was measured in three paddocks – one in the Pemberton region and two in the Busselton region.

The Pemberton experience occurred in relation to studies on whitefringed weevil in a paddock sown to the variety Ruby Lou. The preplant soil monitoring of 100 sampling units did not show the presence of either whitefringed weevil or African black beetle. Prior to harvest, there was a noticeable early senescence of the untreated area over the treated area. The marketable yield and level of insect damage to tubers by a combination of what must have been low populations of both WFW and ABB, are given in Fig. 31.

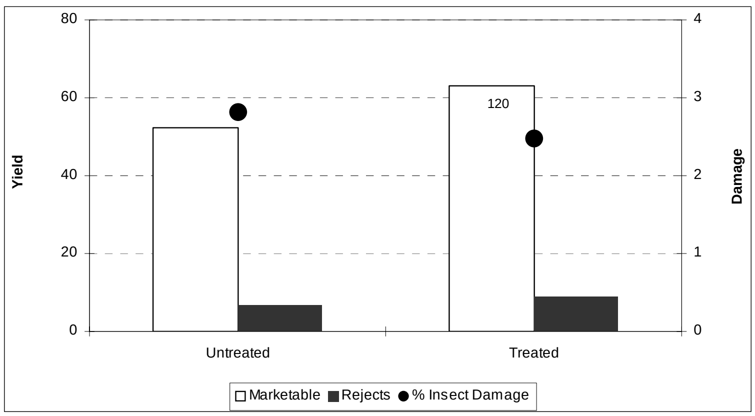

Fig. 31. The yield (t/ha) of marketable potatoes and reject tubers and % tubers damage by whitefringed weevil and African black beetle in a potato crop in an area treated with metham sodium pre-plant and an adjacent untreated area, Pemberton. The figure in the bar representing yield in the metham sodium treated area is the percentage of yield in the treated area to that in the untreated area.

Insect damage levels were low at less than 3% and were similar in treated and untreated areas. The yield of reject tubers was proportionally similar for treated and untreated areas to total yield. So there did not appear to be any positive effects of metham sodium on quality improvement such as control of diseases. The difference in marketable yield may only be ascribed to the use of metham sodium itself.

In relation to studies on ABB in the Busselton region, a similar effect was measured in two paddocks. In one of these crops, two times of harvest for different potato varieties demonstrated similar results. The yield and ABB damage levels for these crops are given in Fig. 32, where Crops 1 and 2 were the varieties Mondial and Nadine respectively, grown in the same paddock and Crop 3 was the variety Granola. The pre-plant density of ABB was 2.8/m^2 in the paddock where Crops 1 and 2 were grown and no ABB were found when soil for Crop 3 was checked.

Despite the beetle damage level of 6% in the untreated portion of Crop 1, the yield of marketable potatoes in areas where metham sodium had been applied was much higher than for the adjacent untreated area, and certainly higher in all cases despite the levels of ABB damage recorded. As was the case for the Pemberton experience, the proportion of total yield that was classified reject was similar for untreated and treated areas.

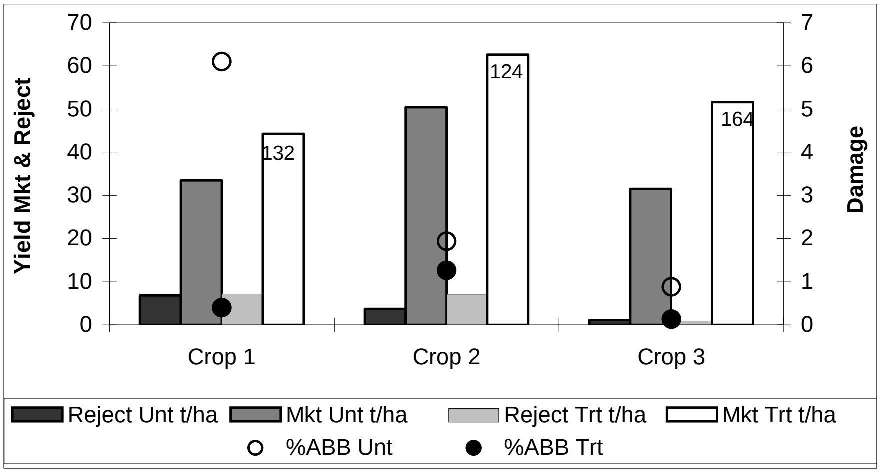

Fig. 32. The yield (t/ha) of reject and marketable potatoes and % tuber damage by African black beetle for three potato crops in areas treated with metham sodium pre-plant and adjacent untreated areas, Busselton, WA. The numbers in the bars showing marketable yield in metham sodium treated areas are the proportion (%) of treated to untreated areas.

This yield boost was not a consistent effect in the Busselton region. In at least one crop where yield data were available between metham treated and untreated areas, no such boost effect was measured.

Technology Transfer

A list of meetings and publications produced during the project are listed in Appendix 6.

<u>Queensland</u>

Most extension during the project has been carried out on a one to one basis with grower co-operators. The project has also been discussed with agricultural consultants working in the industry. The Flyer describing the project was sent out to about 100 growers but the response to the offer to undertake a pre-crop soil check was minimal. However, a few additional trial sites were obtained this way.

Across the industry on the Atherton Tableland potato growers are generally comfortable with the way they deal with soil insects. However, there is still some confusion about which of the available insecticides control which insect pests, which insecticides are approved in which crops (potatoes, peanuts and maize) and to some extent which pests are causing which damage. The soil pest ID kit will help overcome some of these problems. Consultants and resellers largely need to clarify the insecticide issues. Clearly, products should not be recommended when they have no or little activity against a pest, or if the product is not approved in the crop. If pre-crop monitoring for soil insects is to become a routine practice on potato farms, consultants may need to lead the way. Farmers are busy and may not make the commitment to sample in sufficient detail. They are more likely to hire a consultant to undertake the task, partly because they have a better understanding of pests and pest activity throughout a region. For many growers however, the cost of sampling would need to be less than an insurance treatment with a soil insecticide, which provides a certain 'peace of mind'.

A potato field day was held in March 2003 at the Gatton Research Station to discuss the potato research projects being carried out in the Lockyer Valley. Topics included the "Incidence of Brown Fleck in Potatoes", "Water Use Efficiency", "Managing Melon Thrips in Vegetables" and the "Incidence of Rice Root Aphids in local Potato Crops". A handout on the most common aphids found in potatoes was produced and distributed to all those that attended including the local consultants and resellers.

Data to compare clustered versus systematic sampling for whitefringed weevil larvae was examined in detail and reported on at a biometrician's meeting in WA. The details of the paper are: De Faveri, J., Learmonth, S. and De Faveri, S. (2002). Spatial distribution and sequential sampling plan for soil insect pests in potatoes. Spatial Statistics Session: Australasian Genstat Conference, 4-6 Dec 2002, Busselton WA.

<u>New South Wales</u>

At the commencement of the project, grower groups at Robertson, Dorrigo and Guyra were contacted and visited by the chief investigator and the regional collaborators.

The annual project meeting held at Coffs Harbour in September 2003 incorporated a field visit by the project team to Dorrigo, when co-operators and other interested farmers were invited to attend. Unfortunately, numbers attending were low.

Most extension during the project in these districts has been carried out on a one to one basis with grower co-operators. In both districts, potatoes are not a major agricultural pursuit, growers are commonly part-time and production land historically rotates between pasture and potatoes. In Dorrigo in particular, many potato crops are speculatively grown on leased land. These districts are also isolated with regard to technical support from either government agencies or private consultants. While the co-operating farmers were very interested to receive the pest survey data during the project, it is unlikely that the growers will continue to conduct the monitoring themselves. It is therefore unclear how uptake of pre-crop monitoring might be achieved in these circumstances.

During the project growers at Dorrigo have come to understand the importance of black beetle flights into crops and the need to monitor these more objectively. The development of the soil pest ID kit should aid identification of species other than black beetle and whitefringed weevil and their damage. Grower equipment for insecticide application and incorporation is quite variable, making comparisons between treatments at different sites difficult.

A field walk was held at Robertson on 24 April 2003, lead by Sandra Lanz and Robert Spooner-Hart. The purpose of the field walk was to demonstrate to growers how the pre-crop soil sampling is undertaken and to identify the type of insects found. It was also an opportunity to provide information on the work carried out last season in the district and around Australia. Growers in the Crookwell and the Hawkesbury districts were invited also.

<u>Victoria</u>

All extension has been by one-to one discussion between the researcher and farmers. In other research on potatoes in Australia, Horne *et al*. (1999) have highlighted the importance of the source of information before growers will implement change.

All trials conducted in Victoria in this project were conducted in commercial crops with recommendations being implemented immediately. All co-operating growers understood that this was a research project aiming to find results to problems of interest to them. However, after discussions about the work, the methods and the assessments, they were prepared to commit entire crops on the basis of our recommendations.

The good results and the commitments given demonstrate that it is entirely possible to implement the finding of this project immediately if:

(i) growers trust the advice and the source of that advice but also only if

(ii) an advisor is prepared to give advice that may include non-chemical options.

An example of the recommendations given following the assessments is presented in Appendix 5.

<u>Western Australia</u>

The aims and results of much of the project work in WA have been made known to potato growers in soil insect susceptible regions through the one on one contact with crop sampling and associated recommendations on actions required and effects on yield and insect damage.

Forums with potato growers on whitefringed weevil and African black beetle were held with potato growers at Manjimup and Busselton.

A flyer was produced for distribution to growers describing the aims of the project and inviting potato growers to contact their research staff in their respective state to have their crops monitored for soil pests.

Recommendations - scientific and industry

<u>Queensland</u>

Whitefringed weevil

- promote management aspects of area freedom, crop history, planting time and crop rotation to reduce the need for insecticide use against WFW;
- promote pre-crop soil sampling using suggested threshhold of $\geq$ 1 larva per square metre as the basis for deciding whether insecticide use is required;
- investigate the effect of forage sorghum on survival of WFW larvae as a management tactic.

Whitegrubs

- undertake studies to clarify the identity, biology, pest status and management of whitegrubs that affect potato crops in FNQ, with an emphasis on *Lepidiota laevis*, possibly as a joint project with the Bureau of Sugar Experiment Stations;
- develop soil sampling protocols to assess the need to treat for whitegrubs in potato crops;
- investigate insecticide use strategies for protecting potato crops from damage by whitegrubs;
- investigate the use of rotation with legumes and cultivation on the survival of whitegrubs as management tactics.

Wireworms

- undertake studies to clarify the identity, biology, pest status and management of wireworms that affect potato crops in FNQ;
- develop soil sampling protocols to assess the need to treat for wireworms in potato crops;
- investigate insecticide use strategies for protecting potato crops from damage by wireworms.

Rice root aphid

- not seen as a pest during this project, therefore produce a farmnote summarising the findings of this project for grower awareness of this potential pest.

Other soil insect pests - Southeast Queensland

- wireworms, mole crickets and black field crickets were not investigated in this project, but growers comments' suggest they are important. Investigate the role of crop rotation as a management tactic. Investigate pre-crop monitoring strategies to develop treatment threshholds. For this, include the use of baits both as a sampling strategy and a possible control method.

<u>New South Wales</u>

Whitefringed weevil

- promote pre-crop soil sampling using suggested threshhold of $\geq$ 1 larva per square metre as the basis for deciding whether insecticide use is required. Note that WFW is considered to be a minor pest in the Robertson area but this needs to be clarified by further studies.

African black beetle

- promote pre-crop soil sampling using suggested threshhold of $\geq$ 2 ABB per square metre, based on studies in Western Australia as the basis for deciding whether insecticide use is required;

- promote the use of light traps as a warning service for growers to reduce the risk of damage from fly-ins of adults during crop growth; extend the Western Australian permit for use of chlorpyrifos to protect crops from fly-ins after hill-up.

Whitegrubs

- undertake studies to clarify the identity, biology, pest status and management of whitegrubs that affect potato crops in NSW;
- if required, develop soil sampling protocols to assess the need to treat for whitegrubs in potato crops and investigate insecticide use strategies for protecting potato crops from damage by whitegrubs.

Wireworms

- undertake studies to clarify the identity, biology, pest status and management of wireworms that affect potato crops in NSW;
- if required, develop soil sampling protocols to assess the need to treat for wireworms in potato crops and investigate insecticide use strategies for protecting potato crops from damage by wireworms.

<u>Victoria</u>

Whitefringed weevil

- promote pre-crop soil sampling using suggested threshhold of ≥ 1 larva per square metre as the basis for deciding whether insecticide use is required.

Potato wireworm

- promote use of baits for pre-crop soil sampling to assess the need for taking action against PWW as the basis for deciding whether insecticide use is required.

Whitegrubs

- clarify the pest status and threshhold levels for red-headed pasture cockchafer larvae in Victorian potato crops, and whether other species of cockchafer are pests of potatoes;
- undertake studies to assess the role of crop rotation where cultivation is required, in suppressing the abundance of red-headed pasture cockchafer;
- seek extension of the registered label for chlorpyrifos or request a minor use permit to allow chlorpyrifos to be used to protect potato crops from redheaded pasture cockchafer infestations.

<u>Western Australia</u>

Whitefringed weevil

- promote pre-crop soil sampling using a suggested threshhold of ≥ 1 larva per square metre as the basis for deciding whether insecticide use is required;
- CropCare Australia to consider whether to proceed with development work on the soil insecticide bifenthrin as an alternative insecticide for control of WFW larvae;
- review the use of fumigants for WFW control, as new products become available.

African black beetle

- promote pre-crop soil sampling using suggested threshhold of ≥ 2 ABB per square metre as the basis for deciding whether insecticide use is required;
- promote the use of light traps as a warning service for growers to reduce the risk of damage from fly-ins of adults during crop growth;

- seek support from insecticide companies to extend registered labels to include the use of chlorpyrifos for protecting potato crops from fly-ins of ABB after hill-up.

Other soil insect pests and general

- promote awareness of growers of the possibility of damage to potato crops by larvae of other soil pests such as garden weevil and apple weevil;
- if required, develop soil sampling protocols to assess the need to treat for garden weevil and apple weevil and investigate insecticide use strategies for protecting potato crops from damage by them;
- clarify the effects of metham sodium – inconsistent control of WFW and yield boost.

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Acknowledgments

Queensland

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Kyla Finlay - Department of Primary Industries, Victoria (Knoxfield)
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Appendix 1. Estimates of severity and value of losses by soil insect pests in *Australian potatoes, as at December 2000.

State	Region	Production (tonnes)	Value ($)	**Pest & % crop damage					Value of crop damage ($)
				WFW	ABB	PWW	WG	RRA	
Qld	Lockyer/Fassifern	34,000	$13,600,000	0.5				1	$204,000
	Atherton	30,000	$12,000,000	2			3		$600,000
	Bundaberg	18,000	$7,200,000						$0
	Darling Downs	23,000	$9,200,000	1				1	$184,000
	Others	11,500	$4,600,000						$0
		116,500	**$46,600,000**						**$988,000**
NSW	Sydney	5,800	$2,200,000		2				$44,000
	Hunter	3,200	$1,100,000						$0
	Illawarra	5,500	$2,000,000	1	2				$60,000
	Richmond Tweed	1,800	$600,000						unknown
	Mid-North Coast	13,500	$5,000,000	1	2				$150,000
	Northern	10,300	$3,700,000	1	1				$74,000
	North Western	2,800	$1,000,000	0.5	0.5				$10,000
	Central Coast	5,700	$2,000,000						unknown
	South Eastern	1,800	$600,000						unknown
	Murrumbidgee	37,100	$13,500,000	0.5					$67,500
	Murray	49,000	$17,800,000	0.5					$89,000
		136,500	**$49,500,000**						**$494,500**
Vic	Gippsland s	16,000	$7,200,000	0.2		0.1	0.5		$57,600
	Ballarat s	8,000	$3,600,000			0.1	0.5		$21,600
	Otways s	5,000	$2,250,000	0.2		0.1	0.5		$18,000
	King Lake s	3,000	$1,350,000	0.2		0.5	0.5		$16,200
	Portland s	2,000	$900,000	0.2			0.5		$6,300
	Ballarat p	90,000	$17,370,000			0.1	0.5		$104,220
	Otways p	10,000	$2,500,000	0.2		0.1	0.1		$10,000
	Gippsland f	60,000	$21,000,000	0.2		0.1			$63,000
	Gembrook f	10,000	$3,500,000	0.2		0.2			$14,000
	Murray R'vale,SwH f	10,000	$3,500,000						$0
	Geelong f	10,000	$3,500,000	0.4		0.2	0.2		$28,000
	Kooweerup	30,000	$7,500,000	0.2	1	0.1	0.1		$105,000
		224,000	**$66,670,000**						**$443,920**
WA	Metro	9,000	$3,780,000						$0
	Myalup	5,000	$2,100,000		0.5				$10,500
	Busselton	11,600	$4,880,000		3				$146,400
	Donnybrook	4,400	$1,850,000	0.5	1				$27,750
	Manjimup	23,000	$9,660,000	2	0.5				$241,500
	Albany	2,500	$1,050,000	0.2	1				$12,600
		55,500	**$23,320,000**						**$438,750**
	TOTAL	**532,500**	**$186,090,000**						**$2,365,170**

* statistics for potato crops in South Australia and Tasmania are excluded despite soil pests occurring there. Potential collaborators regarded soil pests as being relatively unimportant, but agreed to become involved at a later stage with technology transfer activities.

**Pests are WFW, whitefringed weevil, ABB, African black beetle, PWW, potato wireworm, WG, whitegrubs and RRA, rice root aphid.

Appendix 2. Common and scientific names of insects mentioned in this report.

apple weevil	*Otiorhynchus cribricollis* Gyllenhal
African black beetle	*Heteronychus arator* (Fabricius)
(Atherton pasture scarab)	*Lepidiota laevis* Arrow
blackheaded pasture cockchafer	*Aphodius tasmaniae* Hope
coxsfoot grub	*Rhopaea verreauxii* (Blanchard)
(Dorrigo whitegrub)	*Dasygnathus globosus* Arrow
garden weevil	*Phlyctinus callosus* Boheman
lesser pasture cockchafer	*Australaphodius frenchi* (Blackburn)
potato wireworm	*Hapatesus hirtus* Candeze
(Ravensthorpe whitegrub)	*Ataenius* sp.
redheaded pasture cockchafer	*Adoryphorus coulonii* (Burmeister)
rice root aphid	*Rhopalosiphum rufiabdominalis* (Sasaki)
small lucerne weevil	*Atrichonotus taeniatulus* (Berg)
whitefringed weevil	*Naupactus leucoloma* (Boheman)
yellow-headed pasture cockchafer	*Sericesthis nigrolineata* (Boisduval)

Appendix 3. Details of the light trap used to monitor flight activity of African Black beetles.

Supplied equipment for each individual light trap include:

Body of light trap x 1, including self-contained safety UV light

Lid for light trap x 1

Lid fasteners x 4

Large fasteners x 4

Small fasteners x 4.

Equipment that needs to be purchased for light trap functioning:

Power cord x 1, length is dependant on distance from power outlet.

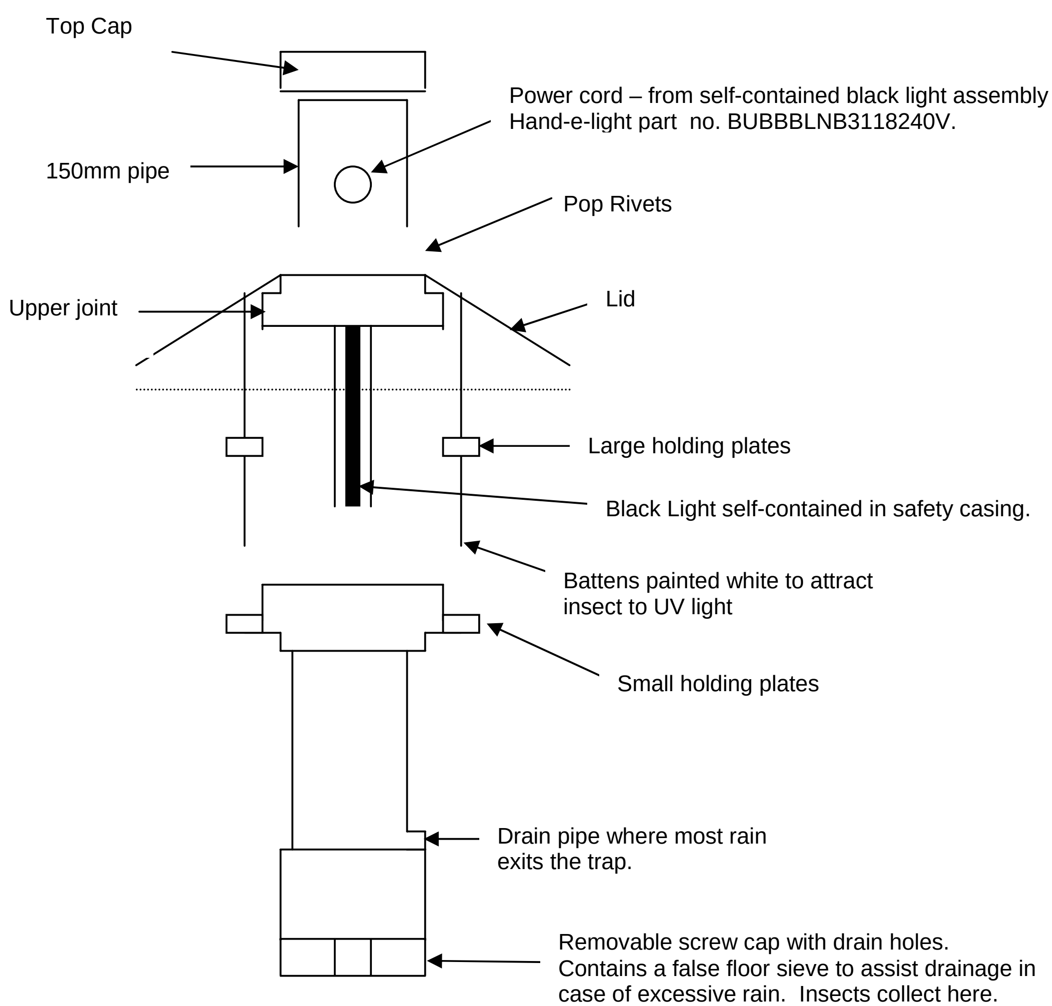
Philip's TL 20W/05 black light globe x 1; (or Hitachi black light LAMF20T9/BL).

Timer x 1; Arlec 24 hour Quick – Set Time Switch (PC899)is the cheaper version and is sufficient if the trap is being placed in an area where power supply is constant. If it is being placed in an area where power supply can be of concern a better timer with reserve power is HPM Digital Timer (Cat 817).

Pop rivets.

6ft star pickets x 2.

Light Trap diagram



Setting up of the light trap.

Firstly attach the lid. To do this remove the grey cap on the power end of the trap. If the lid does not fit over power point near the top of the trap, it will be necessary to remove this by unscrewing four bolts and dislodging it from the trap.

Once the power point is removed, slide the lid down the 150 mm pipe until it sits flush on the upper joint. Drill through the tin lid to the upper joint and insert a pop rivet. Do this four times evenly around the circumference. To fix the lid from the bottom there are 4 right angles supplied. Fix one end of the angle to the upper joint, then the other to the under side of the lid. Fix these evenly around the lid.

Attaching the light trap to the star pickets: also supplied are four large plates and four small plates. The large plates are to be fixed to battens near the top of the trap, one on each side of the batten so they are back to back. These then need to be fixed in line with the star picket holes using 3 x pop rivets each. A hole needs to be drilled through the plates so that a bolt can be used to fasten the trap to the star pickets. The same needs to be done with the small plates, although these are to be placed below the baffles (angled pieces of tin near the base of the battens).

Appendix 4. Economic Injury Level for soil insect pests of potatoes.

Making a decision as to whether to apply pesticide to protect a potato crop from damage by soil insects is based on the value of the reduced return from a potato crop caused by pest damage compared to the cost of using pesticide.

This project sought to estimate crop damage level and therefore the need to apply pesticide from abundance of soil pests prior to planting a potato crop. The decision needs to be made before planting, because most of the soil insects are controlled by pre-plant incorporation of soil pesticides.

Value of losses from soil insect pests

This project provided broad guidelines as to the level of damage as percent tuber damage at crop maturity that may be expected at various pest densities prior to planting. Tuber damage can vary from zero to complete crop loss where the time taken to grade out the damage and the level acceptable by the market can mean a crop is not worth harvesting. The level of damage at which a crop is not worth harvesting is taken at 30%. The value of the lost yield depends on the gross yield and value of potatoes. Yields of potatoes may vary from 30 to 100 t/ha and the value of tubers may vary between $200 and $450/t. Seed potatoes may be worth much more and therefore much lower damage levels than are discussed here would apply. Also, the issue of quarantine and producing seed potatoes that are not infested with live insects has implications for deciding to treat in areas where soil insects are reasonably consistent pests.

Farmers use a variety of means of applying pesticide to soil for insect control. The most common methods include a rotary hoe with a spray boom mounted just in front of the hoe so the insecticide is mixed into the soil, tined cultivators either with a spray boom attached or following a separate pass of a boom spray, in-row jets for banding insecticide into the planting furrow and blade plow for placing metham sodium at depth. For the purposes of this calculation, it is assumed that the insecticides will be applied broadacre using either a rotary hoe or blade plow.

Cost of applying pesticide

The three components considered here to calculate the cost of applying pesticide include labour, machinery and pesticide costs. The three most commonly used pesticides for control of soil insect pests are metham sodium, chlorpyrifos and fipronil. All of the liquid insecticides may be applied using a boom mounted on a rotary hoe, and metham may be applied using a blade plough. The granular insecticide phorate is less commonly used and requires delivery via a granular applicator.

1. Rotary hoe

It is assumed it takes 2.5 hours/ha to incorporate insecticide using a rotary hoe, plus an allowance of half an hour per hectare for preparation, filling and clean-up after application. A pay rate for labour of $25/hr to apply the pesticide is used. Total labour cost is estimated at $75/ha.

Machinery costs are based on a 90 hp tractor with a cost rate of $10.50/hr, a rotary hoe with a cost rate of $9/hr and the spray unit mounted on the hoe is assumed to have a cost rate of $5.00/hr. Total machinery costs are estimated at $24.50/hr or approximately $60/ha.

Insecticide costs as at February 2005 from information supplied by a chemical stockist are included in Table A 2.1 to estimate the total cost of applying insecticide by rotary hoe.

Table A 2.1. Cost of applying insecticide to soil to protect potato crops from soil insect pests where a rotary hoe is used to incorporate the insecticide.

Pesticide	Rate/ha	Cost/L	Cost/ha	Total cost/ha
chlorpyrifos	6 L	$10.60	$64	$199
fipronil – WFW	500 ml	$345	$173	$308
fipronil – PWW	250 ml	$345	$86	$221
metham sodium	500 L	$1.771	$886	$1,021

2. Blade plough

It is assumed it takes 1 hour/ha to incorporate metham sodium using a blade plough, plus an allowance of quarter of an hour per hectare for preparation, filling and clean-up after application. A pay rate for labour of $25/hr to apply the pesticide is used. Total labour cost is estimated at $31.25/ha.

Machinery costs are assumed to be the same as for a rotary hoe; that is, total machinery costs are estimated at $24.50/hr or approximately $60/ha.

Insecticide costs as at February 2005 from information supplied by a chemical stockist are included in Table A 2.2 to estimate the total cost of applying metham sodium by blade plough.

Table A 2.2. Cost of applying metham sodium to soil to protect potato crops from soil insect pests where a blade plough is used to incorporate the insecticide.

Pesticide	Rate/ha	Cost/L	Cost/ha	Total cost/ha
metham sodium	500L	$1.771	$886	$977

3. Granular applicator

The granular insecticide phorate is most likely to be applied at planting, therefore only time to attach, fill and clean the granular applicator is considered here. It is assumed it takes 0.5 hours/ha for these tasks. A pay rate for labour of $25/hr to apply the pesticide is used. Total labour cost is estimated at $13/ha.

Machinery costs for use of a granular applicator are related to the use of the applicator only because the applicator is attached to the potato planting rig. Costs in relation to the use of a granular applicator are estimated at $1/hr or approximately $2.50/ha, assuming a planting rate of 2.5ha/hr.

Insecticide costs as at February 2005 from information supplied by a chemical stockist are included in Table A 2.3 to estimate the total cost of applying insecticide by granular applicator.

Table A 2.3. Cost of applying phorate insecticide to planting rows using a granular applicator to protect potato crops from wireworms.

Pesticide	Rate/ha	Cost/kg	Cost/ha	Total cost/ha
phorate	29kg	$8.80	$255.20	$271

Choosing an insecticide and method of application

This study considers only the pests for which insecticides have been registered – whitefringed weevil, African black beetle and wireworm (see Table 1).

The insecticide a grower uses for control of a particular soil pest will depend on their experiences. Some growers in WA have experienced a yield boost when metham sodium has been used, as discussed in this report. Others have noted an improvement in tuber quality after using metham sodium.

As far as control of soil insects is concerned, the target pest will determine the insecticide chosen also. For example, some growers have experienced control failure with metham sodium for whitefringed weevil, and for the same target, inconsistent control when using chlorpyrifos. However, for control of African black beetle, chlorpyrifos remains a reasonably consistently effective insecticide. For potato wireworm, fipronil, chlorpyrifos and phorate are registered. In Victoria fipronil is used, while in southeast Queensland phorate is more widely used. The latter use may be for pests other than wireworm, whereas in Victoria, potato wireworm is the target pest.

For the purpose of examining the economic injury level, it is assumed that metham sodium is being used for whitefringed weevil control, chlorpyrifos for African black beetle and fipronil for wireworm. Particular growers may choose to use other insecticides and the data provided here would help in an examination of the results for these situations. It is also assumed for this study that a blade plow is used to incorporate metham sodium, while a rotary hoe is used to incorporate insecticide for control of both African black beetle and wireworm.

For an expected yield of 50t/ha and a return at farm gate of $350/t, the percent tuber damage that may be tolerated and what this approximately equates to in terms of insect numbers pre-plant is given in Table A 2.4. For this set of circumstances, a threshhold density of 1 WFW larva per square metre and 2 ABB per square metre can be tolerated. Insufficient data is available for an assessment to be made for potato wireworm at this stage.

Table A 2.4. Density of pests that may be tolerated in potato crops before it is economically justified to apply a soil pesticide to protect the crop, assuming a yield of 50t/ha and a return of $350/t.

Pest	Pesticide	Application method	Cost of application/ha	% tuber damage	Insects/m^2
WFW	metham sodium	Blade plough	$984	5.6	1
ABB	chlorpyrifos	Rotary hoe	$214	1.2	2
PWW	fipronil	Rotary hoe	$236	1.3	na

Appendix 5. Example of a consultant's report to a potato grower on soil sampling.

3 September 2003

Mr Potato Farmer
ACME Trading Pty Ltd

Hello PF

Following are the results of my soil pest sampling, as discussed with you today.

Recommendation: Spray Lorsban on paddock 7/8 and work it in before planting.
No insecticide needed in paddock 11/ 12.

In paddock 7/8 I found three species of cockchafer and whitefringed weevil. One of the cockchafer species (blackheaded) is not a problem in potatoes. Redheaded and yellow headed cockchafers can cause damage. Whitefringed weevil was present but at an extremely low level (one weevil in 20 samples) and so is probably too low to be of much concern.

Redheaded pasture cockchafer (*Adoryphorus coulonii*) was the most abundant species found. Only one of the 20 samples (each 20 x 20 cm x 10 cm deep) had no cockchafers present. The average density of cockchafers at 4 points in the paddock was as follows.

North	100/m^2
	150/m^2
	105/m^2
South	185/m^2

This level of cockchafers is almost certain to cause severe damage.

In paddock 11/ 12 I found no cockchafers. It is likely that cultivation has prevented re-population of the paddock by beetles after the original damaging population had completed their life-cycle.

Appendix 6. A list of meetings and publications produced during the project.

Meetings

The Principal Investigator and Regional Researchers met with potato growers at the commencement of the project in July/August 2001 in:

Victoria - Meeniyan, Thorpdale and Kooweerup

New South Wales - Robertson and Dorrigo

Queensland - Gatton, Mareeba, Tolga, Kairi, Atherton and Walkamin

Forums with potato growers on whitefringed weevil and African black beetle were held with potato growers at Manjimup on 5 June 2002 and Busselton on 3 September 2002, respectively.

A potato field day was held in March 2003 at the Gatton Research Station, Qld.

A field walk was held on 24 April 2003 at Robertson, NSW.

Follow up meetings between the Principal Investigator and Regional Researchers and potato growers were held at Dorrigo and Guyra in New South Wales and Gatton in Queensland in July 2003.

Publications

De Faveri, J., Learmonth, S. and De Faveri, S. (2002). Spatial distribution and sequential sampling plan for soil insect pests in potatoes. Spatial Statistics Session: Australasian Genstat Conference, 4-6 Dec 2002, Busselton WA.

A flyer in pamphlet form printed on A4 paper and folded to 6 pages, was produced in 2002 for distribution to growers in each state represented in the project describing the aims of the project and inviting potato growers to contact research staff to have their crops monitored for soil pests.

Progress reports on the project were presented in Potato Australia in the years 2002, 2003, 2004 and 2005.

A poster on the project was produced for the International Congress of Entomology. S. Learmonth, S., Cannard, M., De Faveri, S, Duff, J, Fay, H, Horne, P, Lanz, S., Spooner-Hart, R., Storey, R and Trainer, S. (2004). Managing soil insect pests of potatoes in Australia. 22nd International Congress of Entomology, Brisbane, Australia 15-21 August 2004.