Integration of crop and soil insect management in sweetpotato

Dean Akers
Australian Sweetpotato Growers Inc

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HAL Project VG09052

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Australian Sweetpotato Growers Inc. (ASPG)

Dean Akers *et al.*

Executive; Australian Sweetpotato Growers Inc. (ASPG)

HAL Project VG09052

Project Leader: Dean Akers
Executive; Member of the Research and Development Committee; Member of the Marketing and Promotions Development Committee
Australian Sweetpotato Growers Inc. (ASPG)

Report prepared by Russell McCrystal of McCrystal Agricultural Services on behalf of ASPG.

Contact: Russell McCrystal
Ph: 0409 397 453
Fax: 07 4145 5522
Email: rmccrystal@gmail.com

Key Personnel:
Rachel Langenbaker (Field Assistant, DAFFQ, Bundaberg Research Facility) Eric Coleman (ASPG Research and Development Committee, Rockhampton) Jeremy Lovatt (Principal Extension Horticulturist, DAFFQ, Bundaberg Research Facility) Iain Kay (Principal Entomologist, DAFFQ, Bundaberg Research Facility) Sandra Dennien (Experimentalist, DAFFQ, Gatton Research Facility) Christina Playford (Biometrician, DAFFQ, Rockhampton) Craig Henderson (Principal Horticulturist, DAFFQ, Gatton Research Facility) David Holt (ASPG member, Lead grower collaborator Bundaberg Troy Prichard (ASPG Treasurer, Lead grower collaborator Bundaberg) Matthew Prichard (ASPG Research and Development Committee, Lead grower collaborator, Cudgen) Brad McCrystal (Independent Freelance Film & Television Producer/Editor)

Purpose of report:
Report on the processes undertaken to improve the awareness and understanding of pest management in sweetpotato farming systems; improve farming practices necessary to provide a broader range of control strategies for the management of sweetpotato pests: sweetpotato weevil (*Cylas formicarius*), root-knot nematode (*Meloidogyne* spp.) and both true and false wireworm (Families Elateridae & Tenebrionidae); develop new technologies that are more targeted to controlling sweetpotato pests and less disruptive to beneficial organisms that can naturally suppress many of the secondary pests that inhabit sweetpotato farming systems.

Funding Sources:

Horticulture Australia Ltd
Australian Sweetpotato Growers Inc.

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Media summary

Key components of the project

The work program included:

- Implementation of a series of pest management workshops across the major sweetpotato production regions, improving grower awareness and understanding of pest and predator basics in the sweetpotato farming systems;
- Implementation of three large scale grower collaborator lead farming systems trials in the Bundaberg, QLD and Cudgen, NSW, production regions, demonstrating improved pest management by taking a whole of crop integrated management approach;
- Implementation of six grower and industry stakeholder participatory learning events across the grower collaborator farming system trial sites;
- Replicated field and pot trial experimentation investigating improved technologies needed for the industry to make significant advancements in the use of IPM within the crop development period.

Industry significance of the project

The Australian Sweetpotato Growers Inc. (ASPG), a group that represents over 90% of Australia's production, identified that they must develop strategies that reduce pest populations of the root knot nematode, sweetpotato weevil and wireworm plaguing their production systems. The combination of all year round sweetpotato production, the stable sub-tropical environment of the production regions and difficulties in managing volunteer sweetpotato growth post harvest all contribute to the ideal conditions for continuous and rapid pest cycles. Subsequently, industry is constantly putting the few currently available insecticides under maximum working pressure. At the onset of VG09052, the only reliable means of controlling insect pests was through the applications of a few broad spectrum insecticides incorporated in the soil prior to planting and foliar applied during crop development.

Key outcomes

The project ran in parallel with an industry wide pest management extension development program arming growers with the knowledge necessary to implement whole of crop integrated management strategies and an extensive pest management research investigation into new pest management technology.

The extension program was focused on better equipping growers and stakeholders with the skills and abilities needed to take a whole of crop integrated pest management approach in sweetpotato farming systems. Improved pest management approaches, both between sweetpotato cropping periods and within the crop development period, were taught and demonstrated on farm. The project secured strong grower and industry stakeholder participation throughout the life of project, engaging with over 260 grower and key industry stakeholder personnel. This has provided improved awareness and understanding of sweetpotato pest management across the sector and lead to significant practice changes to the sweetpotato farming system.

New crop protection technologies were identified that target different stages of pest lifecycles using new application methodologies that are less disruptive to potential beneficial organisms in the sweetpotato farming system. Application technologies have been developed to improve the delivery of crop protectants into the sweetpotato root zone providing improved crop protection times and reducing dependence on large concentrations of soil incorporated insecticides needing to be applied prior to planting.

Recommendations

Further studies to establish reliable pest monitoring methods, particularly for root knot nematode and sweetpotato weevil, are needed. That would greatly enhance growers' ability to manage these pests.

Continual identification of potential pesticides, combined with effective application techniques, is essential in expanding the pest management tools available to growers, as is the identification of new sweetpotato varieties resistant to the key pests.

Identification of the barriers and drivers for the adoption of effective cover cropping systems in sweetpotato whole of crop integrated management systems needs to be undertaken. This knowledge would provide the strategic direction necessary to further improve the uptake of cover cropping systems.

Technical summary

Nature of the problem

The combination of all year round sweetpotato production, the stable sub-tropical environment of the production regions, the susceptibility of the main variety grown, Beauregard, to pest injury and difficulties in managing volunteer sweetpotato growth post harvest all contribute to the ideal conditions for continuous and rapid pest cycles. Subsequently, industry is constantly putting insecticides under maximum working pressure.

Description of the activities undertaken

The work program included: Conducting insect pest management awareness and understanding training; conducting large scale on-farm demonstration trials with lead collaborating growers; testing farming system innovations that minimise pest populations between cropping periods; conducting grower and industry stakeholder participatory learning events at each of the three grower collaborator sites; testing and identifying new potential 'soft options' which have the potential to contribute to sweetpotato IPM systems.

Major project findings and recommendations

Grower & industry stakeholder engagement leading to practice change

Grower and industry stakeholders were engaged in a range of informal (field walks/shed meetings) and formal (workshops) learning activities throughout the project. If participation is a measure of the success of a project, then VG09052 engaging with over 260 participants across 12 structured events is a significant outcome. The implementation of such an extensive vegetable industry development program has relied heavily on the participation of lead growers engaging and driving key project tasks. Research, development and extension were all occurring simultaneously in a participatory learning environment with collaborating researchers, industry service providers and growers all contributing to provide opportunities that maximise the dissemination of information and creation of new problem solving ideas.

The project has seen significant improvements in cover cropping management strategies implemented between the sweetpotato cropping periods across the industry. It has also seen significant improvements with farming practices, particularly chemigation, used to manage sweetpotato pests within the crop development period. These outcomes have been documented and published in a 17 minute video documentary interviewing lead growers showcasing 'Whole of crop integrated management strategies' that they now use in their sweetpotato farming systems to better manage sweetpotato pests.

New technology research investigations

The R&D work program has demonstrated both new delivery methodology and new chemical compounds with new modes of action across the sweetpotato pest spectrum. One insecticide for wireworm (F. Tenebrionidae and F. Elateridae), three insecticides for sweetpotato weevil (*Cylas formicarius*) and one nematicide for root knot nematode (*Meloidogyne* spp.) have been investigated as part of replicated field and pot experiments undertaken by the project.

For the first time a more effective means of delivering smaller amounts of fipronil through drip irrigation systems against wireworm has been demonstrated in a long season (260 plus days) sweetpotato crop. The sweetpotato industry is now armed with the data necessary to pursue a new minor use permit for fipronil in the sweetpotato crop. This new application methodology could potentially significantly reduce the dependence on bifenthrin in the sweetpotato farming system as highlighted by McCrystal (2010).

Thiamethoxam applied through drip irrigation at multiple times in the crop development period was field tested in two replicated trials against sweetpotato weevil. Low sweetpotato weevil pressure in the first field experiment followed by large rainfall events and a prolonged wet period during the second field experiment contributed to poor experimental results. In order to overcome the problem of low weevil pressures at trial sites a novel approach was developed to ensure adequate sweetpotato weevil pest pressure is present during field experimentations. A series of pot trial experiments investigating the activity of plant systemic compounds against feeding injury of adult sweetpotato weevil showed significant and promising results. Two new compounds were identified that have better activity against adult sweetpotato weevil compared to thiamethoxam. These new insecticides need to be further tested to ascertain field efficacy. They would appear to have low impact on beneficial arthropods and potentially have a very good 'IPM fit' if successful. This could significantly reduce the dependency on bifenthrin and chlorpyrifos in the sweetpotato farming system as highlighted by McCrystal (2010).

Improved varietal tolerance levels to root knot nematode were demonstrated in Australian conditions with two recently imported USA varieties, Evangeline and Bienville. Access to USA breeding program germplasm is vital for the Australian sweetpotato industry to secure improved varietal tolerances to major sweetpotato pests and diseases.

Due to the variability of crop development periods that growers are managing in order to maintain regular 12 month supply of sweetpotato into their supply chains, research needs to continue to identify and develop technologies that can be applied accurately throughout the crop development time directly to the developing sweetpotato root system providing lasting crop protection through to commercial harvest.

Chapter 1: Improving awareness and understanding of pest and predator basics

Introduction

At the completion of project VG05037, 'Improving the management of sweetpotato soil insects', McCrystal (2010) reported that the sweetpotato industry needed to develop strategies that reduce the large pest populations of wireworms (Families Elateridae and Tenebrionidae), root-knot nematodes (*Meloidognye* spp.) and sweetpotato weevils (*Cylas formicarius*) present in the sweetpotato production systems. The combination of all year round sweetpotato production, the stable sub-tropical maritime climates of the major production regions, the relatively concentrated aggregation of sweetpotato businesses and the difficulties in managing volunteer sweetpotato growth post harvest were all contributing to ideal conditions enabling continuous and rapid pest cycles. Subsequently, industry was constantly putting crop protectants and farm profitability under maximum working pressure.

The first phase of project VG09052 was charged with improving the growers awareness and understanding of sweetpotato pests and their predators. This was seen as the first step towards equipping growers to successfully arrest the pest populations plaguing their production systems. Pest management workshops were to be delivered that improved the basic knowledge and awareness needed to achieve a whole of crop integrated management approach.

Sweetpotato growers needed to shift their focus from solely controlling the pest problem within the crop development period using routine broad-spectrum chemical applications to more effectively reducing pest populations between the sweetpotato cropping periods. The project team was confident that there was a range of better farm management strategies that focused on farm hygiene and cover cropping that growers could adopt that could reduce these pest problems.

Within the crop development period, growers required the knowledge and understanding to more effectively deliver chemical compounds to the right place, at the right time and targeted to the correct pest and life stages of that pest. At the onset of this project the two pesticide application or delivery methods used by growers in the control of pests were soil incorporation prior to planting and routine foliar applications during the crop development phase. The project team perceived that trickle irrigation technology was not being adequately utilised as an effective delivery system for crop protectants. Trickle irrigation systems would allow industry the ability to apply smaller amounts of product, more often to target different life stages of the major pests at various crop stages. This ability was also seen as vital as crop development times vary from 120 days to 260 days, depending on the time of year the crop is planted. To expect crop protectants soil incorporated prior to planting to provide adequate protection out to 260 days was a significant risk to the industry.

The sweetpotato industry, through project VG09052, wanted to ensure that it was developing production systems that could maximise the working life of all current registered crop protectants and all potential crop protectants entering the market place. It also perceived this as a strategic approach necessary for attracting the everdiminishing dollar investments of the agri-businesses bringing new crop protectant technologies to the market.

Materials & methods

Heisswolf *et al.* (2010a) and Heisswolf *et al.* (2010b) produced an excellent workshop manual and trainer's handbook, respectively, for the identification of insects, spiders and mites in vegetable crops. Session plans were adapted from the trainer's handbook and workshop manual and specifically adapted to meet the needs of the Australian sweetpotato industry. The project team reviewed the above-mentioned guides and developed the workshop sessions after undertaking two grower-planning meetings in Bundaberg and Cudgen production regions, on 29/10/2010 and 22/3/2011 respectively. As a result of grower input, the workshops were structured into two sessions so that each session could be delivered in an informal learning environment over a two-hour period. A key strategy used ensured teaching segments were broken up with hands-on interactive rotating workstations so that growers could physically get up and move about while still achieving learning outcomes. The workshops also included opportunities for growers to reflect and self-assess their understanding of the knowledge delivered throughout the workshop. Every grower attending the workshops received a folder that included key handouts relating to the day's topics and activities. A key industry stakeholder sponsored each workshop and a lucky door prize that had relevance to the industry was awarded.

Due to the interest gauged in the Bundaberg production region, it was decided to split the workshops there into two groups. This maintained a smaller group size enabling maximum interaction between those personnel delivering content during the workshops and grower participants attending the workshops. This was seen as vital during workstation activities in particular.

The first session (Table 1.1) of each workshop covered topics that included insect classification, insect groups, identifying major pests and collecting and preserving pests for identification. This session included workstations where growers could use different types of equipment necessary to identify both major and secondary sweetpotato pests. Actual insect specimens were collected from sweetpotato fields and utilised in these sessions.

The second session (Table 1.2) covered topics that included sweetpotato pest monitoring, identification of beneficial organisms, tools for pest population management and Chemigation for effective pest control. This session again included workstations where growers could use different types of equipment necessary to identify beneficial organisms. Actual insect specimens were collected and utilised in these sessions.

Following the delivery of most activities and workshops run by the project team, a phone call was made to participants to obtain feedback. These calls were designed to capture gains in learning in relation to knowledge and attitudes. Growers were asked to rate the value of these events from one to five, one being Strongly Agree, two being Agree, three being Neutral, four being Disagree and five being Strongly Disagree.

The dates and locations of the planning meetings and the workshops are shown in Table 1.3.

Table 1.1: Detailed schedule for Workshop Session 1

Time	**Duration**	**Content**	**Person**
2:15 pm	5 mins	ASPG Welcome & Introduction Grower to set the scene	Dean Akers (Tues) Duane Joyce (Wed)
	10 mins	Introduce Workshop schedule & handout workshop manuals (Topics covered & day's activities)	Russell McCrystal (Tues & Wed)
2:30 pm	30 mins	Insect classification	Iain Kay (Principal Entomologist QLD DAFF)
		Insect groups	Iain
3:00 pm	15 mins	Rotating work stations - Hand lenses & insect identification - Digital scopes & insect identification - Microscopes & insect identification - Competition to estimate number of nematode on slide . PRIZE : bag of Fumigator & hand lenses	Sandra Dennien (Experimentalist QLD DAFF) Jerry Lovatt (Principal Horticulturist QLD DAFF) Rachel Langenbaker (Field assistant QLD DAFF)
3:15 pm	25 mins	Identification of major pests (particularly major & secondary sweetpotato pests)	Iain
		Insect biology & ecology	Iain
	5 mins	General root knot nematode introduction	Russ
3:45 pm	15 mins	Activity to test knowledge	Jerry
4:00 pm	15 mins	Introduction to IPM	Iain
4:15 pm	5 mins	Close workshop - Summarize day's content & brief summary of next workshop & dates Thankyou to workshop sponsors, DuPont and Pacific Seeds	Russ
4:20 pm		BBQ & Beers	BBQ – Rach/Sandy&Russ

Table 1.2: Detailed schedule for Workshop Session 2

Time	Duration	Content	Person
2:15 pm	5 mins	ASPG Welcome & Introduction Grower to set the scene	Dean Akers (Tues) Duane Joyce (Wed)
	10 mins	Introduce Workshop schedule & handout workshop manuals (Topics covered & day's activities) & give an overview of the global trends in agchem	Russ (Tues & Wed)
2:30 pm	5 mins	Recap on workshop 1 (identification)	Iain
	10 mins	IPM	Iain
2:45 pm	15 mins	Monitoring for sweetpotato pests - Sweetpotato weevil - Wireworm - Root knot nematode - Silverleaf whitefly - Aphids	Russ
3:00 pm	15 mins	Rotating work stations focusing on beneficial organisms - Hand lenses & insect identification - Digital scopes & insect I.D. - Microscopes & insect I.D.	Sandy Jerry Rach
3:15 pm	10 mins	Tools for better pest population management	Jerry
		Crop hygiene is Champion of the tool kit!!!	Jerry
	10 mins	Pesticide application strategy and product developments	Russ
3:35 pm	20 mins	Chemigation	Craig Henderson (Principal Horticulturist QLD DAFF)
3:55 pm	15 mins	Interactive QUIZ to re-affirm workshop learnings	TEAM
4:15 pm	5 mins	Close of workshop - Summarize day's content & brief summary of next workshop & dates Thankyou to workshop sponsors, Bayer Crop Sciences	Russ
4:20 pm		BBQ & Beers	BBQ – Rach/Sandy&Russ

Results

Improved awareness and understanding of sweetpotato pest management was achieved throughout the delivery of VG09052 workshops in the two major sweetpotato production regions of Australia.

According to data published in the Australian Sweetpotato Industry Profile (ASPG 2012) the target audience comprised a total of 68 production enterprises or levy payers. The majority of producers were situated in Queensland (Bundaberg, Gatton and Rockhampton areas) and New South Wales (Cudgen) with 50 and 13 producers respectively. Northern Territory, Western Australia, South Australia and Victoria had 2, 1, 1 and 1 producer respectively.

The project designed & implemented:

- one grower planning meeting in Bundaberg;
- one grower planning meeting in Cudgen;
- four half-day workshop sessions in Bundaberg;
- one full day comprising two workshop sessions in Cudgen.

A total of 26 growers attended the initial planning meetings. This represents approximately 38% of the Australian sweetpotato industry participating in the planning process (Table 1.3).

A total of 86 growers took part in the two part pest management workshop series. Thirty growers attended workshop one held at Bundaberg Research Station on the 13th and 14th July 2011, representing 60% of the Queensland sweetpotato industry. Thirty growers attended workshop two held at Bundaberg Research Station on the 24th and 25th August 2011, representing 60% of the Queensland sweetpotato industry. It was noted that the workshop series undertaken in Bundaberg achieved good retention rates of grower attendees from workshop 1 returning for workshop 2. Sixteen growers attended the workshop series conducted at the Cudgen Leagues Club on the 16th November 2011, representing 100% of the NSW sweetpotato industry (Table 1.3).

Learning outcomes of workshops included:

- ability to identify primary and secondary pests of sweetpotato;
- understanding of the biology and ecology of primary and secondary pests of sweetpotato;
- understanding of what decision support tools are available for sweetpotato weevil, wireworm and root knot nematodes and the utilisation of the data that they provide;
- ability to identify predators of sweetpotato pests;
- modes of delivery for crop protectants and future product development;
- chemigation principles and technologies for the more accurate delivery of crop protectants to the effective root zone of the sweetpotato crop.

Feedback gained from phone surveys undertaken after workshops showed that 100% of participants either strongly agreed or agreed that the pest management workshops:

1. helped them gain a better understanding of insects (mean score = 1.3);
2. provided relevant information for managing insect pests in their farming business (mean score = 1.2) ;

3. will assist them to manage insect pests in their farming businesses in future (mean score = 1.4).

Table 1.3: Dates, venues, content and participation rates at planning meetings and workshops

Date	Venue	Content presented	Number of grower attendees	% of Australian sweetpotato industry present *
29th October 2010	Bundaberg – Kellys Beach Resort	Aims & objectives for VG09052 – developed plan for workshops and trials	14	20% (28% QLD industry)
22nd March 2011	Cudgen – Paddon Farms	Aims & objectives for VG09052 – developed plan for workshops and trials	12	18% (92% of NSW industry)
13th July 2011	Bundaberg Research Station	Insect pest (major and secondary) and predator identification	11	16% (22% of QLD industry)
14th July 2011	Bundaberg Research Station	Insect pest (major and secondary) and predator identification	19	28% (38% of QLD industry)
24th August 2011	Bundaberg Research Station	Introduction to integrated pest management	17	25% (34% of QLD industry)
25th August 2011	Bundaberg Research Station	Introduction to integrated pest management	13	19% (26% of QLD industry)
16th November 2011	Cudgen leagues club	AM: Insect pest and predator identification PM: Introduction to integrated pest management	16	23% (100% of NSW industry)
TOTAL PARTICIPATION			**112**	

*Participation percentage calculated on number of growers, based on ASPG Inc. figures, rather than on area of production.

Discussion

The workshop series was a great success. The workshops were not only successful in engaging with a high proportion of the Australian sweetpotato industry but they also promoted opportunities for interactions to occur between private and public researchers, extension officers, industry service suppliers and growers. This created stronger relationships and provided the significant momentum necessary to move into the next phase of the project.

Chapter 2: Achieving practice change through large scale on-farm alternative cropping system trials and decision support sites

Introduction

The project capitalised on the momentum generated through growers gaining a better knowledge and understanding of sweetpotato pests and their management. The project team identified three lead farmers who were eager to facilitate large scale on-farm decision support sites and demonstration trials. These sites were seen as strategic in order to drive adoption of better farming practices that required a whole-of-crop integrated management approach.

Throughout the pest management workshop series in 2011 the sweetpotato growers attending regularly reported inconsistent results with the use of nematicides applied through the trickle irrigation systems for the control of root knot nematode. In comparison, very few reports of wireworm and sweetpotato weevil damage were being brought to the group's attention throughout this same period. The above feedback confirmed survey results by McCrystal (2010), which identified that more than 90% of sweetpotato growers perceived root knot nematode as the major threat to their production systems.

The three major pests of sweetpotato ranked in order in 2010 were root knot nematode, wireworm and sweetpotato weevil.

The project team's primary focus with ongoing work was therefore on the management of root knot nematode populations in sweetpotato production systems. The project team, in conjunction with the three lead growers, perceived that these inconsistent results could be attributed to the combination of:

- higher than normal wet seasons;
- high root knot nematode numbers present at planting;
- irrigation/chemigation techniques that were not delivering the correct amount of nematicide accurately into the root zone.

It was therefore decided to investigate those factors affecting root knot nematode numbers that we could manage:

a) What can be improved between cropping periods to better manage cover crops to reduce pest population levels.
b) What can be improved within the cropping period to more effectively manage the pests from damaging the developing sweetpotato crop.

The project team was confident that by utilising the issue of root knot nematode management as the catalyst for driving the adoption of better ground management techniques between the cropping periods it would not only achieve reductions in nematode populations, but indirectly provide a significant impact on the sweetpotato weevil populations inhabiting the cropping systems. McCrystal (2010) demonstrated that using good farm sanitation practices was effective in reducing the presence of sweetpotato weevil populations across an isolated sweetpotato farming system in

Rossmoya, QLD. The use of pheromone trapping on a grid pattern assisted that project by identifying hot spots of weevil concentration on the farm. These hot spots were always found to be in association with areas of poor crop sanitation following commercial harvest. Pheromone trapping undertaken throughout VG09052, as done throughout project VG05037, again clearly demonstrated that in areas where volunteer sweetpotato growth post harvest was not controlled sweetpotato weevil populations were at their highest levels.

McCrystal (2010) reported that trickle irrigation was the dominant method of irrigation, with 90-95% of growers using it to both establish and grow their sweetpotato crops through to commercial harvest in comparison to 55% in 2006. As trickle irrigation has fast become the dominant method for both growing the sweetpotato crop and delivering critical crop protectants to the root zone, ASPG Inc perceived it as fundamental that VG09052 should demonstrate best bet trickle applied chemigation techniques on a commercial scale. This would not only have an immediate impact for currently registered and permitted compounds required to be applied through trickle irrigation but would also provide a strong platform from which the industry can begin to build a more effective integrated pest management program.

The three study sites where farming innovations were trialled under real commercial scale farming conditions were run from Autumn 2012 to Spring 2013. At these sites pest monitoring techniques were used as the primary tool to measure the impact of cultural controls in reducing pest population levels. These large commercial field scale trials were not structured as scientifically replicated experiments but were observational and took a participatory approach with the lead growers and field day participants.

Materials & methods

VG09052 project team identified three leading sweetpotato growers between the age of 30 – 40 years who were willing to establish large scale farming system trials on their properties and host grower and industry stakeholders at various stages throughout the investigation period. These sites had a variety of soil types and were situated in both the major production regions of Bundaberg QLD and Cudgen NSW. These sites were fundamental to the project's ongoing extension program necessary to drive improved integrated pest management strategies in sweetpotato farming systems.

Site A) Matthew Prichard, Cudgen NSW production region.

Demonstrating improved delivery method techniques for chemigation and quantifying the efficacy of Vydate® L in conjunction with best bet cover crop management strategies

A problem block was identified by the lead grower as having incurred significant economic losses due to root knot nematode in the previous commercial crop of sweepotato. The Cudgen observation site was an unreplicated field sized trial of 2 ha with two treatments, namely a large area treated with Vydate® L (240 g a.i./L oxamyl) compared to an untreated area (1.5 m by 135 m).

The grower collaborator had reviewed previous chemigation techniques for delivering nematicide to the cropping area. It was concluded that the previous techniques were inadequate at placing product accurately in the root zone and evenly across the field. It was decided to change the approach by:

- reducing the size of treatment areas;
- increasing operational pressures in the trickle irrigation system;
- using a direct injection chemigation unit;
- shifting the injection unit closer to the delivery area;
- monitoring wetting fronts through the soil profile;
- taking note of injection times and flush times.

Treatments (Table 2.1) were applied into the subsurface drip system using a direct injection unit situated at the beginning of the field. The T-tape used was Model 508-20-380. Emitter spacing was 20 cm delivering 760 ml per hour of water at 10 psi.

The trial site was sampled prior to planting for root knot nematodes on two occasions by collecting soil cores at random from across the trial area. All soil cores were taken using a stainless steel soil augur tube that was 2.5 cm in diameter to a depth of 10 cm below the soil surface. Approximately 40-50 soil cores were taken and combined, mixing gently, and a sub-sample of approximately 400 g then sent for nematode analysis at DAFF QLD. The treatment plot areas were also sampled during the crop development phase at 50 days after planting (DAP) and commercial harvest (212 DAP). At 212 DAP soil samples were taken and sent for analysis for each of the sub-sampling plot areas within treatment blocks to quantify root knot nematode numbers per 200 g soil. For each of these smaller sub-sampling plot areas 10 cores were collected and combined gently for the sample.

At commercial harvest (212 DAP) five sweetpotato plants were sampled from each of 10 sub-plots randomly selected through each treatment block area. Storage roots were washed and visually assessed for root knot nematode damage. All harvested storage roots were weighed and categorised into three grades, First Grade, Second Grade and Unmarketable. The criteria used to define these grades are given in Table 2.2 and shown in Figures 2.1 – 2.4.

The dates for key activities undertaken at the Cudgen trial site are:

November 2011:	Significant crop loss due to root knot nematode infestation detected at commercial harvest
Dec 2011 to Jan 2012:	Ground management – mechanical cultivation/bare fallow
February 2012:	Sorghum cover crop established using combine seed planter
18 April 2012:	Soil samples collected across block and analysed for root knot nematode levels
24 December 2012:	Sampled trial area for root knot nematode levels
14 January 2013:	Trial area planted to sweetpotato
18 January 2013:	Applied Vydate® L at 18 L/ha (5 DAP)
1 February 2013:	Applied Vydate® L at 8 L/ha (19 DAP)
4 March 2013:	Grower event, 10 growers (15% of Australian Industry/ 77% of the NSW industry) Nematode soil assessment from both treatment areas (50 DAP)
14 May 2013:	Grower event, 13 growers (19% of Australian Industry/ 100% of NSW industry)
14 August 2013:	Commercial and final harvest (212 DAP) Nematode soil assessment from both treatment areas

Table 2.1: Treatments evaluated in the Site A trial.

Treatment	Delivery System	Total rate product /ha	Application regime
1. Vydate® L	Sub-surface drip	26 L/ha	18 L/ha at planting followed by a single application of 8 L/ha 14 days after initial application
2. Untreated control	Not applicable	0	Not applicable

Table 2.2: The criteria for root knot nematode damage used to define the commercial grades of sweetpotato.

Commercial grade	Infestation level	Category
First Grade	No visual presence of root knot nematode damage	**1**
Second Grade	Root knot nematode damage visually present. Defects to skin included: pimples large eyes	**2**
Unmarketable	Root knot nematode damage visually present. Defects to skin included: galling cracking pinched-in ends	**3**

Figure 2.1: Category 2 defect to skin - pimples

Figure 2.2: Category 2 defect to skin – large eyes

Figure 2.3: Category 3 defect to skin – galling and cracking

Figure 2.4: Category 3 defect to skin – pinched in ends

Site B) Dave Holt Rubyanna Rd, Bundaberg QLD production region.

Commercial scale observational trial comparing the efficacy of Vydate® L and the soil incorporation of molasses at six rates in conjunction with best bet cover crop management strategies.

A problem block was identified by the grower collaborator as having incurred significant economic losses due to root knot nematode in a previous crop of sweepotato. The Rubyanna Rd observation site was an unreplicated field sized trial with six molasses treatment rates with or without Vydate® L applied through the trickle system. Treatment plot areas were 400 m by 1.5 m, split in the middle allowing for nematicide to be applied to one side and not to the other. The trial design is shown in Table 2.3.

Conclusions drawn from a root knot nematode pot trial with molasses conducted on tomatoes by Vawdrey *et al.* (1997) suggest that an application rate of molasses equivalent to a field rate of 1.13 t/ha regularly applied to the soil reduced root galling and nematode reproduction rates. In this Case Study, molasses treatments (Table 2.4) were applied to the soil surface via a GPS guided spray ground rig prior to soil incorporation. Vydate® L (Table 2.4) was applied into the subsurface drip system using a pressure differential unit situated at the beginning of the field. The trickle irrigation was Netafim tape. Emitter spacing was 20 cm delivering 760 ml per hour of water at 10 psi.

The trial site was sampled prior to planting for root knot nematodes on one occasion by collecting four soil samples across the 4 ha field. Each sample was representative of approximately one hectare. All soil cores were taken using a stainless steel soil augur tube that was 2.5 cm in diameter to a depth of 10 cm below the soil surface. Approximately 40-50 soil cores were taken and combined from each of the samples, mixing gently, and a sub-sample of approximately 400 g then sent for nematode analysis at DAFF QLD The treatment areas were also sampled during the crop development phase. At 28 DAP soil samples were collected from the six molasses treatment areas, which had not received Vydate® L. Between 20-30 soil cores were taken and combined from each of these treatment areas of 300 m^2. At 125 DAP, 15 soil cores were collected and combined from each of the treatments two small sub sampling plot areas, then sent for analysis at DAFF QLD to quantify root knot nematode numbers per 200 g soil.

At commercial harvest (125 DAP) five sweetpotato plants were sampled from each of two sub-plots randomly selected in each of the 12 treatment block areas. Storage roots were washed and visually assessed for root knot nematode damage. All harvested storage roots were weighed and categorised into three grades, First Grade, Second Grade and Unmarketable. The criteria used to define these grades are given in Table 2.2 and shown in Figures 2.1 – 2.4.

The dates for key activities undertaken at the Rubyanna Rd trial site are:

September 2011:	Commercial crop of Beauregard planted
January 2012:	Significant crop loss due to root knot nematode infestation detected at harvest
February to May 2012:	Ground management practices
March:	Mechanical cultivation and sorghum cover crop planted
June:	Sorghum mulched and mechanically incorporated
July:	Grower Event: Over sow triticale through trash with Conag minimal till seeder
September 2012:	Grower Event
October 2012:	Cover crop incorporated, molasses treatments applied and ground preparation including forming hills
1 November 2012:	Beauregard crop planted
5 March 2013:	Commercial harvest

Table 2.3: Site B trial design

T1 A)	T1 B)
T2 A)	T2 B)
T3 A)	T3 B)
T4 A)	T4 B)
T5 A)	T5 B)
T6 A)	T6 B)

Table 2.4: Treatments evaluated in the Site B trial.

Treatment A Pre-plant soil incorporated molasses at varying rates	Treatment B Pre-plant soil incorporated molasses at varying rates + post plant chemigation of Vydate® L applied at 18 L/ha delivered through the trickle irrigation system
1. Molasses 1000 L/ha	1. Molasses 1000 L/ha + Vydate® L
2. Molasses 2000 L/ha	2. Molasses 2000 L/ha + Vydate® L
3. Molasses 4500 L/ha	3. Molasses 4500 L/ha + Vydate® L
4. Molasses 2500 L/ha	4. Molasses 2500 L/ha + Vydate® L
5. Molasses 1600 L/ha	5. Molasses 1600 L/ha + Vydate® L
6. Untreated Control	6. Untreated Control + Vydate® L

Site C) Troy Prichard Moore Park Rd, Bundaberg QLD production region

Commercial scale observational trials investigating the efficacy of fenamiphos soil incorporation prior to planting with best bet cover crop management strategies.

A problem block was identified by the grower collaborator as having incurred significant economic losses due to root knot nematode in a previous crop of sweepotato. The affected block was commercially harvested during the winter period of 2011. The Moore Park Rd observation site was a replicated field sized trial with three replicates and a split plot design. There were five treatments (Table 2.5), combinations of sorghum varieties, planting method, and insecticide seed coating, each of which was split to compare each treatment with or without regular mulching. Split plots were 100 m by 4.5 m in size. The sorghum varieties included for trialling were Jumbo and Fumigator both of which are distributed by Pacific seeds. Pacific seeds had developed Fumigator with reportable superior bio fumigation attributes in comparison to their older standard forage variety, Jumbo. Figure 2.5 shows the trial design. Cover cropping treatments were applied early in October 2011.

In September 2011, prior to the sowing of the cover crop treatments, the field site was sampled for presence of the sweetpotato pests wireworm and root knot nematode.

Wireworm sampling was done by placing baits throughout the trial area. Baits were cut cubes of sweetpotato that were buried approximately 20 cm below the soil surface and left for 10 days. After 10 days the cubes were dug up, brushed and then assessed for wireworm feeding injury. Presence or absence of wireworm feeding holes was recorded.

In October 2011 the trial site was sampled once the cover cropping and ground management treatments were applied. Each of the treatment plot areas (4.5 m by 200 m) were sampled by collecting soil cores at random from throughout the plot area. All soil cores were taken using a stainless steel soil augur tube that was 2.5 cm in diameter to a depth of 10 cm below the soil surface. Approximately 30-40 soil cores were taken and combined, mixing gently, and a sub-sample of approximately 400 g then sent for nematode analysis at DAFF QLD. Each of the treatment plot areas and subsequent split plot areas were also sampled in August 2012. Twenty soil cores were collected and combined for each treatment area (4.5 m by 100 m). At commercial harvest (210 DAP) soil samples were taken and sent for analysis for each of the sub-sampling plot areas within treatment plots to quantify root knot nematode numbers per 200 g soil. For each of these smaller sub-sampling plot areas 10 cores were collected and combined gently for the sample.

During the establishment phase of the cover crop treatments 1m by 1m quadrant counts were taken to measure germination rates of cover crops, and numbers of volunteer sweetpotato plants, broadleaf weeds and more specifically Convolvulaceae species. The presence of residue sweetpotato roots were also recorded per quadrant. A total of 20 sites were sampled per treatment plot area.

At the end of the cover cropping period and at the onset of ground preparation for the subsequent commercial crop of Beauregard, the trial site was again sampled for root knot nematode.

In December 2012 ground preparations were made, which included the soil incorporation of the nematicide fenamiphos as directed by the label. Some observational plots (20 m by 1.5 m) were left untreated in replicates 2 and 3 for cover cropping treatments 3 and 4.

At commercial harvest (210 DAP) ten sweetpotato plants were sampled from each of the treatment plot areas. Storage roots were washed and visually assessed for root knot nematode damage. All harvested storage roots were weighed and categorised into three grades, First Grade, Second Grade and Unmarketable. The criteria used to define these grades are given in Table 2.2 and shown in Figures 2.1 – 2.4.

Soil samples were taken from each sample plot area from replicates 2 and 3 to measure the presence of root knot nematodes at commercial harvest.

The dates for key activities undertaken at the Moore Park Rd trial site are:

October 2011:	Identified site and collected pest population data
	Established cover crop treatments
November 2011:	Quadrant germination assessments
February 2012:	Began mulching cover crops on bottom half of trial

April 2012:	Grower event
July 2012:	Grower event
	Over sow mulched section of trial with triticale
September 2012:	Full incorporation of all treatments
	Begin ground preparation for next commercial crop
December 2012:	Soil incorporated nematicide treatment
	Pulled hills up for planting
January 2013:	Planted Beauregard 5th January (20 cm plant spacing)
June 2013:	Grower event
August 2013:	Commercial harvest (210 DAP)

Table 2.5: Treatments evaluated in the Site C trial.

	Sorghum cover crop variety (planting rate)	Planting method	Insecticide seed coating
1.	Fumigator (15 kg/ha)	Combine seed drill with tynes	-
2.	Fumigator (15 kg/ha)	Catros speed tiller with Gandi seed boxes	-
3.	Jumbo (25 kg/ha)	Combine seed drill with tynes	Cruiser® (thiamethoxam) seed coated
4.	Jumbo (25 kg/ha)	Combine seed drill with tynes	-
5.	Bare Fallow	Combine seed drill with tynes	-

Figure 2.5: Field layout of cover cropping treatments at planting and the subsequent areas of regular mulching (F1) versus no mulching (F2). Plot areas highlighted red included sub-plots without soil incorporated fenamiphos prior to planting.

	R1					R2					R3				
	T1	4	3	2	5	2	5	1	4	3	5	3	4	1	2
F1															
F2															

Results

Site A) Matthew Prichard Cudgen NSW production region.

The site was sampled for root knot nematodes on the 18th April 2012 when a total of 15 soil samples were collected and assessed. Counts ranged from zero through to 27 root knot nematodes per 200 ml soil solution. The average across all 15 sites was 6.26 root knot nematodes per 200 ml soil solution.

The trial site was sampled prior to planting on the 24th December 2012 for root knot nematodes by collecting random soil samples from the entire trial area. No root knot nematodes were detected. The commercial crop of Beauregard was planted on 14th January 2013.

On the 4th March 2013 at 50 DAP both untreated and treated areas were sampled for root knot nematodes. The untreated areas recorded a count of 909 root knot nematodes in a 200 ml soil solution in comparison to the treated areas recording a count of 38 root knot nematodes in a 200 ml soil solution.

At commercial harvest (212 DAP) soil root knot nematode counts were taken from across 10 sub-sample plots within each of the treatment areas. An average of 2737.6 root knot nematodes per 200 ml soil solution recorded from the untreated control areas in comparison to 1373.9 root knot nematodes per 200 ml soil solution in the Vydate® L treatment areas.

Rainfall figures from the Bureau of Meteorology for Coolangatta airport, QLD and the NSW town of Murwillumbah, situated approximately 12 km and 17 km respectively from the trial site, recorded higher than average rainfalls for the month of February 2013. Coolangatta airport recorded 369.4 mm of rain, well above the average of 171.2 mm. Murwillumbah recorded 353.8 mm of rain, well above the average of 231.3 mm.

Root knot nematode infestation on sweetpotato was visually detected at the commercial harvest at 212 DAP as both second grade (pimples and enlarged eyes) and unmarketable (galling, cracking and pinched ends) roots. There were notable differences found between treatments for the number of sweetpotato roots damaged by root knot nematodes (Table 2.6).

The Vydate® L treatment demonstrated notable improvements in storage root protection from root knot nematodes compared to the untreated control. The Vydate® L treatment recorded an average of one unmarketable (category 3) storage root in comparison to the untreated control, which recorded an average of 8.1 unmarketable storage roots. This is approximately 6% of total yield deemed as commercially unmarketable due to root knot nematodes infestation when using Vydate® L treatment in comparison to approximately 57% of total yield deemed as commercially unmarketable when no nematicide treatment was used.

The Vydate® L treatment recorded an average of 14.2 category 2 storage roots in comparison to an average of 6.1 storage roots recorded for the untreated control plots.

The Vydate® L treatment recording an average of 2.6 category 1 storage roots per plot in comparison to no category 1 storage roots for the untreated control plots.

Table 2.6: The mean storage root numbers and weights assessed per five plants at commercial harvest (212 DAP) at Site A.

Treatment	First Grade (Undamaged)		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
Vydate® L 18L/ha + 8 L/ha	2.6	0.33	14.2	2.76	1	0.19	17.8	3.28
Untreated	0	0	6.1	0.96	8.1	1.3	14.2	2.26

Site B) Dave Holt Rubyanna Rd, Bundaberg QLD production region.

On the 10th August 2012. root knot nematode soil counts ranging from zero to five per 200 ml soil solution. Three out of the four samples recorded zero root knot nematode counts.

The trial was sampled for nematodes on two further occasions, at 28 DAP and at harvest. The results are given in Table 2.7. The molasses plus Vydate® L treatment areas were not sampled at 28 DAP.

No pattern was evident from this data to suggest any correlation between root knot nematode counts and molasses treatments applied.

Table 2.7: Root knot nematode numbers per 200 mL soil solution at Site B.

Molasses rate (L/ha)	Root knot nematode numbers in Treatment A at 28 DAP	Root knot nematode numbers in Treatment A at 125 DAP	Root knot nematode numbers in Treatment B at 125 DAP
1000	0	334	9
1600	2	198	182
2000	2	818	20
2500	11	450	568
4500	16	482	97
0	5	198	182

The commercial crop of Beauregard grown over a 125 day period between October 2012 and March 2013 planted at 20 cm spacing yielded on average 86 tonne per hectare. This is a significantly high crop yield.

The results of root damage assessments at harvest are shown in Tables 2.8 and 2.9.

Those areas not treated with nematicide recorded a mean of 9.16 unmarketable storage roots at commercial harvest. This represents 36% of the storage roots as unmarketable. Those treatment areas where Vydate® L was applied recorded no unmarketable (category 3) storage roots at commercial harvest (Table 2.8).

The data in Tables 2.7 and 2.9 indicate no trend to suggest that a single application of any rate of molasses incorporated into the soil before planting could reduce build up of nematode numbers present in the soil or the severity of damage to the sweetpotato storage roots.

Table 2.8: Mean numbers and weight of storage roots per five plants at commercial harvest (125 DAP) in areas treated or not treated with Vydate® L at Site B.

Treatment	First Grade		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
Vydate® L 18L/ha	23.25	9.66	4.5	3.71	0	0	27	12.94
Untreated	1.5	0.89	24.41	8.38	9.16	4.56	32.83	12.65

Table 2.9: Mean counts and weight of storage roots per five (5) plants at commercial harvest (125 DAP) in the molasses only treatments (Treatments A) at Site B.

Molasses soil treatment	First Grade		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
1000L/ha	0	0	32	9.45	9.5	4.44	41.5	13.89
1600L/ha	3	1.92	28.5	9.47	6	3.94	33	12.4
2000L/ha	6	3.42	19	7.44	7.5	4.6	29.5	13.75
2500L/ha	0	0	30.5	8.96	12	5.06	36.5	11.49
4500L/ha	0	0	17	6.91	9	4.89	26	11.8
Untreated	0	0	19.5	8.1	11	4.48	30.5	12.58

Site C) Troy Prichard Moore Park Rd, Bundaberg QLD production region.

Root knot nematodes were detected across all plots at the establishment of cover crop treatments in October 2011 (Table 2.10).

At the completion of the cover cropping management period, 30th August 2012, root knot nematode were again detected across all treatment plots (Table 2.10). Root knot nematode counts recorded for the Fumigator sorghum planted with the Combine and with the Catros, which had not been mulched, recorded counts of 395 and 214 respectively. In comparison counts of 88 and 9 were recorded for treatments 1 and 2 respectively where the Fumigator sorghum had been mulched a number of times. This result may indicate the benefits of mulching to smother out nematode host plant species more effectively in comparison to leaving the Fumigator sorghum variety to stand.

The next stage that root knot nematode soil counts were recorded was at commercial harvest (210 DAP). Whatever advantages are gained by good cover cropping management techniques are rapidly lost with the onset of planting of sweetpotato. All treatment areas recorded a notable increase in the presence of root knot nematodes at commercial harvest of the sweetpotato crop. No trend is evident to suggest any one particular cover cropping or bare fallow ground management strategy implemented between October 2011 and August 2012 will result in a reduced root knot nematode population through to commercial harvest.

Table 2.10: Mean nematode soil counts collected from Site C.

	30th October 2011	30th August 2012		7th August 2013	
		Never Mulched	Mulched	Never Mulched	Mulched
T1	19.5	395	88	3477	1365
T2	29.5	214	9	3612	2731
T3	29.5	45	27	2610	3094
T4	38.5	0	18	2284	2824
T5	423.5	75.5		2348.5	

Minimal differences were recorded between sorghum planting techniques in relation to mean germination rates recorded just after cover crop establishment on 18/10/2011 and 3/11/2011 respectively (Table 2.11). The only notable differences were between germination rates recorded at cover crop establishment for the Fumigator sorghum planted using the combine planter, 44.14 and 43.17 on the 18/10 and 3/11 respectively, compared to mean germination rates recorded for Fumigator sorghum planted using the Catros multi disc speed tiller with Gandi seeder boxes, 53.01 and 59.39 on 18/10 and 3/11 respectively. The Catros method may have not been as easy to accurately calibrate using the Gandi box seed delivery equipment. There were no notable differences with the two establishing treatments of Jumbo sorghum. The Jumbo sorghum coated in thiamethoxam was used to investigate whether wireworm could be a limiting factor in the establishment of cover crops in the sweepotato production systems. The mean germination rates for Jumbo sorghum seed not coated (T4) with insecticide were 72.18 and 89.06 on 18/10/2011 and 3/11/2011 respectively. The mean germination rates for Jumbo sorghum seed coated with insecticide (T3) were 70.62 and 77.8 on 18/10/2011 and 3/11/2011 respectively. This indicates that there was not a detectable level of wireworm present throughout the site area. All treatment plots recorded similar presence of sweetpotato plants, sweetpotato roots, general broadleaf weeds and other Convolvulaceae plant species on 18/10/11 and 3/10/11.

Table 2.11: Mean germination counts collected from across treatment plots just after crop establishment on two occasions, 18/10/11 and 3/10/11 respectively at Site C.

	Date	Sorghum plants	Sweetpotato plants	Sweetpotato roots	General broadleaf weeds	Convolvulaceae spp. weeds
T1	18/10/11	44.14	1.21	0.61	30.78	0.20
	3/11/11	43.70	0.89	0.11	22.76	1.11
T2	18/10/11	53.01	1.03	0.79	11.70	0.61
	3/11/11	59.39	0.60	0.46	19.28	1.14
T3	18/10/11	70.62	0.53	0.37	19.23	1.00
	3/11/11	77.18	0.50	0.30	13.00	0.85
T4	18/10/11	72.18	0.94	0.35	22.96	0.44
	3/11/11	89.06	0.60	0.25	10.98	0.96
T5	18/10/11	0	1.74	0.41	17.73	0.49
	3/11/10	0	0.00	0.00	0.00	0.00

This commercial crop of Beauregard, grown over a 210 day period between January 2013 and August 2013, planted at 20 cm spacing, yielded on average 61 tonne per hectare across the trial area. This is a good crop yield for this growing period.

The average number of unmarketable storage roots recorded at commercial harvest was 14 in those areas where no nematicide was applied. Those treatment areas where fenamiphos was applied recorded an average of 8.8 unmarketable (category 3) storage roots at commercial harvest (Table 2.12). This equates to 28% unmarketable yield in the untreated areas in comparison to 17.7% in the fenamiphos treated areas. Fenamiphos has provided some level of protection over the life of the crop.

The greatest number of first grade storage roots was recorded for the cover cropping treatment of Jumbo sorghum planted using a combine seeder, achieving an average of 11.6 first grade storage roots at commercial harvest. This same treatment also recorded an average of 2.33 unmarketable storage roots, which was the least number of unmarketable storage roots recorded at commercial harvest (Table 2.13). The Jumbo sorghum planted using the combine seeder also recorded top total yields of 69.5 storage roots weighing 19.71 kg. Those treatments with the highest unmarketable yield were bare fallow and Jumbo sorghum with insecticide seed coating planted with the combine seeder, recording 10.66 and 13.83 unmarketable storage roots respectively. The bare fallow treatment recorded no first grade marketable storage roots at commercial harvest.

The commercial harvest yield data found very little evidence to suggest that there was any advantage in either mulching or not mulching cover crops in regards to the management of root knot nematode damage in a sweetpotato cropping systems (Table 2.14).

Table: 2.12: Results presented are the mean counts and weight (kg) of storage roots assessed per ten plants at commercial harvest (210 DAP) comparing areas treated with fenamiphos and those areas that were not at Site C.

Treatment	First Grade		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
fenamiphos	5.3	1.59	35.44	9.78	8.8	3.23	49.5	14.61
Untreated	0.6	0.32	33.6	8.9	14	4.77	48.2	13.95

Table 2.13: Results presented are the mean counts and weight (kg) of storage roots assessed per ten plants at commercial harvest (210 DAP) for each treatment at Site C.

Cover crop treatment	First grade		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
Fumigator/ Combine	6.6	2.08	41.17	13.0	6.33	3.45	53	18.19
Fumigator/ Catros	0	0	53.66	13.36	7	2.29	60.66	15.66
Jumbo with Cruiser®/ Combine	1.6	0.884	32	9.97	13.83	4.76	47.16	15.47
Jumbo/combine	11.66	3.52	55.5	14.58	2.33	1.61	69.5	19.71
Bare Fallow	0	0	37.83	9.62	10.66	4.01	48.5	13.63

Table 2.14: Results presented are the mean counts and weight (kg) of storage roots assessed per ten plants at commercial harvest (210 DAP) comparing areas treated with different cover crop management strategies at Site C.

Cover crop management	First grade		Second grade		Unmarketable		Total Yield	
	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)	Total	Total weight (kg)
Never mulched	7.5	2.16	43	11.58	8.75	3.39	58	16.78
Mulched 3 times	3.6	1.44	48.16	13.87	6	2.67	57.16	17.74
Bare Fallow	3.44	1.49	47.83	18.10	7.5	4.43	57.33	23.29

Grower and industry stakeholder participatory field walks

The project engaged with a total number of 151 grower and industry stakeholder participants across the six field walk events held at these grower collaborator lead farming system trials. The results are presented in Chapter 4: Technology transfer in Table 4.2.

Discussion

The primary purpose of these sites was to help facilitate practice change across the sweetpotato industry. A series of field day events were held at these three sites between Autumn 2012 to Spring 2013. These events allowed lead growers to share their key findings with other growers attending. This allowed the project team the opportunity to reaffirm knowledge and understanding gained from the pest management workshop series and promote key integrated management strategies that were better able to manage pests in the sweetpotato farming systems. The key findings were published in an industry feature film documentary with lead growers sharing about what practice changes they have now implemented on farm.

Grower & industry stakeholder participatory field walks

Growers met a total of six times during an 18-month period to discuss and observe trial site activities. A total of over 150 participants attended these activities over the six occasions. A number of key industry stakeholders also attended these activities, including major marketing agents that supply the two major retail chains, rural supply businesses, agricultural machinery businesses, Universities and State department agencies.

The success of this project has been evident across the industry by the significant purchasing of new minimal tillage cultivation equipment with seed boxes and more accurate chemigation equipment. VG09052's success has been complemented by running parallel to the Reef Rescue program where sweetpotato growers were given the financial incentive to purchase the new capital equipment. Twelve sweetpotato businesses representing a large percentage of the industry's annual sweetpotato production accessed Reef Rescue grants during the 2011/2012 and 2012/2013 financial years in the Bundaberg region.

Root knot nematode soil counts and damage thresholds

When no nematicides were applied to the developing sweetpotato crop unacceptable levels of economic loss due to root knot nematode infestation at commercial harvest occurred at all three sites when soil population counts were low or undetectable at or prior to planting.

The Cudgen NSW site recorded non-detectable levels of root knot nematode prior to planting and at commercial harvest recorded an average of 2737 root knot nematodes, resulting in a 57% unmarketable yield. The Rubyanna Rd QLD site root knot nematode soil counts recorded prior to planting ranged from zero to five root knot nematodes per 200 ml of soil and at commercial harvest recorded an average of 413 root knot nematodes per 200 ml of soil, resulting in a 36% unmarketable yield. In areas where no nematicide was soil incorporated prior to planting at the Moore Park Rd QLD site soil counts ranged from non-detectable levels to 40 root knot nematodes per 200 ml soil and at commercial harvest recorded an average of 2703 root knot nematodes, resulting in a 28% unmarketable yield.

Stirling (2000) reports that counts ranging from 8 to 100 eggs and juveniles/200 ml soil is a relatively low population density and is close to the limit of detection. It is also stated that root knot nematodes can reach damaging levels leading to unacceptable economic loss from very low densities in vegetable crops such as tomatoes, eggplants and capsicums due to the pest's rapid life-cycle and the crops' 130 day developmental periods. It could be argued that tomato, eggplants and capsicums are less susceptible than sweetpotato to economic loss from root knot nematode as the infestation does not take place directly on the saleable end product as is in the case for sweetpotato storage roots. Due to long crop development times of the Beauregard sweetpotato variety (120 to 260 days) and the stable temperatures experienced in major sweetpotato production regions, it is highly plausible that economic thresholds for root knot nematode soil populations could be below the limit of detection for standard nematode extraction techniques.

Between sweetpotato crops root knot nematode control (Cover cropping)

Cover cropping and good ground management between Beauregard sweetpotato crops can reduce nematode soil populations to low levels, however not to a level where commercially a grower can afford to leave a nematicide out of the crop protection program within the time frames observed during this project period.

Jumbo sorghum planted using the combine seeder achieved the highest subsequent sweetpotato total yields at the Moore Park Rd QLD trial site (Site C). This cover cropping treatment also achieved the highest subsequent sweetpotato first grade (category 1) marketable yields in comparison to the other cover cropping or ground management treatments.

Bare fallow ground management trialled at the Moore Park Rd QLD site (Site C) was able to reduce nematode soil populations to low levels but, as these levels were not able to achieve improved subsequent sweetpotato marketable yields at commercial harvest in comparison to other cover cropping techniques, the benefit of bare fallow ground management is questionable. These sweetpotato yield results indicate that the benefits of best bet cover cropping strategies are wider ranging than just for pest control. Grower collaborators perceived that these wider ranging benefits from cover cropping included increased return of organic matter to the soils, improved soil structure and general soil health. They also saw improved erosion control during high rainfall events as a result of increased organic matter residues.

Grower collaborators observed that the Jumbo variety of sorghum agronomically performed the most consistently across the widest range of soil types and environmental conditions in comparison to the sorghum variety Fumigator. Jumbo tillered back better after mulching in comparison to Fumigator.

In light of these project observations it is concerning that the variety Jumbo is no longer available commercially from Pacific Seeds.

Within crop root knot nematode control (nematicides/molasses)

Vydate® L applied at 18 L/ha at planting and then again at 8 L/ha 14 days after planting demonstrated effective control of root knot nematodes and protection of the sweetpotato storage roots from root knot nematode damage at commercial harvest compared to the untreated area.

Good product delivery provided adequate crop protection from root knot nematodes throughout a higher than average rainfall period on soils with particularly high drainage rates.

Applying molasses before planting does not control nematodes.

Fenamiphos, soil incorporated prior to planting, demonstrated some level of protection to sweetpotato roots from root knot nematode damage at commercial harvest compared to the untreated areas.

Chapter 3: Field experiments to identify new technology

a) Report on the efficacy of fipronil (Regent® 200SC) applied through sub surface drip irrigation at various crop development stages to control wireworm in sweetpotato.

Long cropping season (260 days)

Introduction

The aim of the experiment reported here was to test the efficacy of fipronil (Regent® 200SC) injected through trickle irrigation against the group of soil dwelling pests commonly referred to as either true (F. Elateridae) or false (F. Tenebrionidae) wireworms on the sweetpotato variety Beauregard.

Sweetpotato growers in Australia commonly apply multiple preventative insecticides, which are soil incorporated prior to planting, against these pests because the economic consequences of wireworm damage are great and there is no strategy that can predict fields at risk. Results reported by McCrystal (2010) from a field trial undertaken between October 2009 and March 2010 at Bundaberg Research Station showed that fipronil applied through the trickle irrigation system during the 140 day crop development time was effective against wireworm in the sweetpotato cropping system.

Those results provide strong evidence to suggest that fipronil applied at the rate of 250 mL product/ha directly to the root zone of the sweetpotato crop can effectively prevent wireworm feeding injury. The finding addresses the industry's long standing need to successfully control actively feeding wireworm in the later stages of crop maturity. The sweetpotato crop is vulnerable to insect feeding injury from storage root initiation right through to commercial harvest. Storage root initiation can occur at any stage between 21 to 42 days after planting (DAP) and commercial harvest can occur anywhere from 140 DAP through to 260 DAP.

It was concluded that investigations then needed to be made to test the effectiveness of applying the 250 mL/ha rate at various stages during the crop development period over a 200 plus day maturing crop. Chemigation treatment timings will be referred to as days before commercial harvest (DBCH). Days before commercial harvest or DBCH is an important consideration when providing protection to the sweetpotato root zone through to commercial harvest from damaging wireworm populations. Wireworm larvae are highly mobile in the soil profile and therefore are able to move in and out of the sweetpotato root zone to feed when they require or are no longer inhibited by an insecticidal barrier. Growers report significant wireworm injury occurring as little as two weeks prior to commercial harvest. It is probable that later larval stages, rather than younger larvae recently hatching from a fresh egg lay, are responsible for significant wireworm injury at such late stages in the crop development period. For this reason DBCH is an important factor to consider when investigating crop protection for wireworm in sweetpotato farming systems.

This report presents the findings of two investigations undertaken:

1. A trial from May 2010 to February 2011 at Cudgen, NSW
2. A trial from February 2011 to October 2011 at Bundaberg, QLD.

These are considered the longest growing periods for sweetpotato in the Australian production system and represent crops at risk of incurring wireworm feeding injury late in the crop development period.

Materials and methods

Cudgen, NSW:

The field experiment was a randomised block design with five treatments and three replicates (Figure 3a.1). Plots were three rows wide by 12 m long. The middle row was the datum row and either side was a buffer row. Treatments are given in Table 3a.1. Fipronil was applied as the product Regent® 200SC, which contains 200 g of fipronil/L. Bifenthrin was applied as the product Talstar® 250EC, containing 250 g bifenthrin/L.

The trial site was sampled for wireworm prior to planting to estimate the potential wireworm threat. This was achieved by placing 20 baits throughout the trial area. The baits were cut cubes of sweetpotato that were buried approximately 20 cm below the soil surface and left for 20 days. After 20 days the cut cubes were dug up, brushed and assessed for wireworm feeding injury. Presence or absence of wireworm feeding holes was recorded.

In Treatments 4 and 5 the pre-plant soil insecticide was applied through the grower collaborator's ground rig. This allowed the insecticide to be applied to the soil surface directly in front of a tractor operating a rotary hoe that incorporated it into the soil.

The post planting trickle irrigation Treatments 2, 3 and 5 were applied into the subsurface drip system with a water powered dosing machine supplied by Netafim, called a Dosatron D45 RE 3. The Dosatron was installed directly into the water supply line which enabled delivery of the insecticide at a constant dosing ratio in proportion to the flow required to service the Netafim sub-surface drip system. The tape used had emitter spacing of 0.3 m delivering 1 litre per hour of water at 10 psi. Pressure control valves were used to ensure pressure and flow was maintained during the treatment delivery time.

The depth fipronil was delivered to the root system was managed through the use of Full Stops. Full Stops are a wetting front detection device. Two Full Stops were placed in treatment 2 at 20 cm and 30 cm below the soil surface. Once the Full Stop at 20 cm detected the wetting front, fipronil was injected through the sub surface drip system for approximately five minutes. Irrigation continued for a further 10 minutes after the completion of the fipronil injection. The Full Stop at 30 cm below the soil surface would then detect the wetting front, confirming the delivery of fipronil to the sweetpotato root system.

Sampling was conducted on three occasions during the life of the field trial at 155 DAP, 201 DAP and at commercial harvest at 263 DAP. Plots were sub-sampled by removing a total of five plants from the datum rows. To minimise plant disruption in the plot, a buffer of two plants was maintained between each subsample. The samples were then washed and visually assessed for wireworm feeding injury. The assessment consisted of two grades based on levels of commercial marketability. Presence of wireworm feeding injury was deemed unmarketable. Absence of wireworm feeding injury was deemed as marketable.

Key dates of key activities undertaken at Cudgen trial site:

May 2010	Incorporated soil insecticides
24 May 2010	Planted trial
17 Sept 2010	Injected fipronil into treatments 2 and 3 at a rate of 250 mL/ha (145 Days before commercial harvest (DBCH))
27 Oct 2010	First sample harvest (155 DAP)
27 Oct 2010	Injected fipronil into treatments 3 & 5 (105 DBCH)
22 Dec 2010	Second sample harvest (201 DAP)
22 Feb 2011	Commercial harvest (263 DAP)

Figure 3a.1: Cudgen and Bundaberg experimental field design.

REP 1	1
	2
	3
	4
	5
REP 2	1
	3
	4
	2
	5
REP 3	3
	2
	1
	4
	5

Table 3a.1: Application rates of insecticides and methods of application.

Treatment	Pre-plant soil incorporation	Post plant trickle injection
1	untreated control	untreated control
2	-	Fipronil 250 ml product/ha at 145 DBCH
3	-	Fipronil 250 ml product/ha at 145 DBCH & 105 DBCH
4	Bifenthrin 2 L product/ha	-
5	Bifenthrin 2 L product/ha	Fipronil 250ml product/ha at 105 DBCH

Bundaberg QLD:
The trial equipment used to undertake the Cudgen, NSW, trial was used for the Bundaberg field trial, necessitating the field design layout used in Cudgen be replicated in Bundaberg. The field experiment was a randomised block design with five treatments and three replicates (Figure 3a.1). Plots were three rows wide by 30 m long. The middle row was the datum row and either side was a buffer row.

Pre-plant wireworm sampling, and insecticide application methods and treatments (Table 3a.1) were identical to those used in Cudgen trial.

Sampling was conducted on three occasions during the life of the field trial, at 160 DAP, 222 DAP and at commercial harvest at 251 DAP. Plots were sub-sampled by removing a total of five plants from the datum rows. To minimise plant disruption in the plot a buffer of two plants was maintained between each subsample. The samples were then washed and visually assessed for wireworm feeding injury. The assessment consisted of two grades based on levels of commercial marketability. Presence of wireworm feeding injury was deemed unmarketable. Absence of wireworm feeding injury was deemed as marketable.

Key dates of key activities undertaken at Bundaberg trial site:

14 February 2011	Incorporated soil insecticides to treatments 4 and 5
16 February 2011	Planted trial
3 March 2011	Treatment 2 at rate of 250 ml/ha equivalent of fipronil (236 DBCH)
26 July 2011	First sample (160 DAP)
2 August 2011:	Treatment 2, 3 and 5 at a rate of 250 ml/ha equivalent of fipronil (84 DBCH)
27 September 2011	Second harvest (222 DAP)
25 October 2011:	Commercial harvest (251 DAP)

For both the Cudgen and Bundaberg trials analyses of variance were conducted on the percentage of storage roots damaged by wireworm feeding out of the total number of storage roots collected. The comparison between treatments was made using a protected least significant difference (l.s.d at 5%) test. Genstat Release 11.1 was used for all analyses.

Results

Cudgen NSW:
At 155 DAP no wireworm feeding injury was detected on sweetpotato roots from any of the experimental plots.

At 201 DAP wireworm feeding injury was detected in the untreated control plots. There were no significant differences between treatments for the level of unmarketable roots due to wireworm feeding injury. Mean percentage of damaged roots are presented in Table 3a.2.

At commercial harvest undertaken at 263 DAP wireworm feeding injury was visually detected and significant differences were found between treatments (Table 3a.2). The untreated control recorded 18.3% of its harvested storage roots as unmarketable due to the presence of wireworm feeding injury. There were significant differences between treatments for the percentage of unmarketable storage roots (P=0.047, lsd 14.24). Treatment 3 recorded 0% of harvested storage roots as unmarketable, which was significantly less than the untreated control. Treatment 2 recorded 9.9% of harvested storage roots as unmarketable, which was not significantly less than the untreated control and treatment 3. Treatment 4 recorded 20.3% of storage roots as unmarketable, which was significantly greater than treatment 3 and was not significantly different from the untreated control. Treatment 5 recorded 19.5% of storage roots as unmarketable, which was significantly greater than treatment 3, but was not significantly different from the untreated control.

Table 3a.2: Average percentages of storage roots with wireworm feeding injury at commercial harvest 22 Feb 2011 (263 DAP) at Cudgen.

Treatments	Mean percentage of damaged roots at each sampling occasion	
	201 DAP	263 DAP
1. Untreated control	11.6	18.3 b[#]
2. fipronil at 145 DBCH	0	9.9 ab
3. fipronil at 145 & 105 DBCH	0.8	0.0 a
4. bifenthrin soil incorporated prior to planting	2.6	20.3 b
5. bifenthrin soil incorporated prior to planting/fipronil at 105 DBCH	1.2	19.5 b
l.s.d	n.s.	14.24
F ratio probability	P= >0.05	P=0.047

[#] Means followed by the same letter are not significantly different at the 5% level.

Bundaberg QLD:

Mean percentage of damaged sweetpotato roots recorded at160, 222 and 251 DAP are presented in Table 3a.3. Wireworm feeding injury was visually detected on harvested sweetpotato roots at each sample harvest. Wireworm feeding injury in the untreated control plots was low across all three sample harvests. The trial site had very low pest pressure throughout the trial period. There were no significant differences between treatments for the level of unmarketable roots due to wireworm feeding injury.

Table 3a.3: Average percentages of storage roots with wireworm feeding injury at commercial harvest 25 Oct 2011 (251 DAP) at Bundaberg.

Treatments	Mean percentage of damaged roots at each sampling occasion		
	160 DAP	222 DAP	251 DAP
1. Untreated control	4.0	5.9	7.8
2. fipronil 250 mL product/ha at 236 DBCH & 84 DBCH	5.5	10.2	16.4
3. fipronil 250 mL product/ha at 84 DBCH	12.5	9.3	20.5
4. bifenthrin soil incorporated prior to planting	3.9	11.2	13.0
5. bifenthrin soil incorporated prior to planting/fipronil at 84 DBCH	1.4	10.0	12.1
l.s.d	n.s.	n.s.	n.s.
F ratio probability	P= >0.05	P= >0.05	P= >0.05

Discussion

Cudgen:
Levels of wireworm feeding injury in the untreated control were not as high as expected at the Cudgen NSW trial site. McCrystal (2010) reported higher levels of wireworm feeding injury in untreated control plots in trials undertaken in the Cudgen NSW production region between 2006 and 2009. Wireworm feeding injury and commercial loss were still evident at commercial harvest (263 DAP).

These results provide evidence to suggest that fipronil applied at two points in the crop development period at the rate of 250 mL/ha of product directly to the root zone of the sweetpotato crop can effectively prevent wireworm feeding injury out to commercial harvest at 263 DAP.

Bundaberg:
This field experiment experienced low wireworm feeding injury levels. The low level of damage that was recorded was highly variable across the trial site. This was likely due to the generally cooler and wetter than normal growing season. Frequent heavy rain throughout the early stages of the crop's development caused severe water logging at this site. Van Herk and Vernon (2006) reported that field flooding in British Columbia achieved 90% mortality in 8.6 days for the wireworm species *Agriotes obscurus* and *Agriotes lineatus.* This may explain the lack of damage on storage roots in October 2011. Other wireworm baiting activity undertaken across the district during this same period found no injury to cut sweetpotato baits buried and left for a 20 day period.

The significant results found in the Cudgen long season investigation are pivotal for changing agri-chemical usage in the crop. It is now feasible that growers could move away from the single large applications of agri-chemicals at planting to smaller multiple applications throughout the crop's development, providing greater and more consistent wireworm control.

b) Report on the efficacy of thiamethoxam applied through sub surface drip irrigation at various crop development stages to control sweetpotato weevil damage in sweetpotato.

Introduction

This report has been compiled in collaboration with Craig Henderson of Agri-Science Queensland, Department of Agriculture, Fisheries and Forestry, based on experimental work conducted by Russell McCrystal, formerly of the same organisation. Russell McCrystal undertook this work in collaboration with ASPG Inc lead HAL project VG09052 and Syngenta Australia. Both Craig Henderson (QDAFF) and Ken McKee (Syngenta Australia) have agreed for this report to be included in VG09052 final report.

Thiamethoxam applied through drip irrigation at multiple times in the crop development period was field tested in two replicated trials against sweetpotato weevil at the Bundaberg Research Facility. Low sweetpotato weevil pressure in the first field experiment followed by large rainfall events and a prolonged wet period during the second field experiment contributed to highly variable experimental results. However, a novel approach was developed for the methodology required to establish and maintain adequate sweetpotato weevil pest pressures leading up to the testing period. This required trial buffer rows, located either side of the datum rows, to be established with Beauregard a minimum of 6 months prior to the onset of the trial period. This would vary dependent on the time of year testing was to be taking place.

McCrystal (2010) recommended experiments to further investigate the efficacy of thiamethoxam against sweetpotato weevil, to support its legal use in Australian sweetpotato production systems.

This report details experimental work conducted to investigate a proposed use pattern of thiamethoxam applied using shallow, sub-surface drip irrigation in sweetpotato production systems.

Materials & methods

An initial field experiment was abandoned due to the absence of any sweetpotato weevil. A second experiment was instigated in the same block, using the residual sweetpotato plants as infective hosts to supply sweetpotato weevil populations to the main experimental plots.

The experiment was a randomised complete block design, with 7 treatments replicated 4 times in blocks. Each plot consisted of 3 sweetpotato rows (buffer rows either side of a central data row). Plots were 15 m long, with an additional 4 m of buffer row between plots. The treatments were:

1. **Untreated control**. No pesticides applied for weevil management.
2. **Industry current practice**. Foliar spray application of 0.25 L/ha of Talstar® (250 g/L bifenthrin EC formulation) at 5, 33, 61, 89 and 117 days after planting (DAP).
3. **Actara® low**. Drip irrigation application of 125 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 6 DAP.
4. **Actara® medium**. Drip irrigation application of 188 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 6 DAP.
5. **Actara® high**. Drip irrigation application of 250 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 6 DAP.
6. **Actara® soil applied**. Pre-plant- rotary hoed application of 1 000 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 6 days before planting.
7. **Not reported**. Another pesticide under evaluation, data not presented.

Treatments 3-5 were applied into the subsurface drip system with a water powered dosing machine, supplied by Netafim®, called a Dosatron D45 RE 3®. The Dosatron® was installed directly into the water supply line which enabled delivery at a constant dosing ratio in proportion to the flow required to service the sub-surface drip system. Emitter spacing was 0.2 m delivering 1 litre water per hour at 70 kPa. Pressure control valves were used to ensure pressure and flow was maintained during the treatment delivery time.

The sweetpotato crop was grown using standard district fertiliser, irrigation and other cultural practices. Standardised, virus-free sweetpotato cuttings were planted on 14 October 2010.

Rainfalls in October (70 mm) and November (97 mm) were very close to the respective monthly medians. However 507 mm in December 2011 (including 218 mm over 5 days late in the month) was 500% of the long term monthly median. In January, the total of 193 mm was 50% above the median, whilst 69 mm in February was 40% less than the median for that month.

Although FullStop® wetting front detectors were installed to collect leachate from the drip applications of insecticide, due to a malfunction in the refrigeration system used for storing the samples, they were frozen and thus rendered unusable.

Plants were assessed for weevil damage on 3 occasions during the experiment. On each occasion, 10 contiguous plants were harvested (tops and roots) from the data rows.

The first harvest was at 57 DAP. Storage roots were identified, and classed as weevil damaged (evidence of weevil tunnelling on the root), or clean. The number and total weight of each root class were recorded for each plot.

At the second harvest, 118 DAP, the storage roots were classified and recorded as above. In addition, 5 randomly selected tops were examined for evidence of weevil larvae tunnelling in the stems, and the percentage of affected plants recorded.

At the final, commercial harvest, 144 DAP, the same process as noted for the second harvest was repeated.

Storage roots from the untreated controls and various Actara® treatments were sent to Syngenta laboratories for residue analysis (results not reported here).

Standard analysis of variance was used, with log transformations required for weevil affected root data in the first two harvests of the field experiment. Despite high observable weevil numbers in the field experiment, damage to plants and roots was still highly variable between plants and replications. Where analysis of variance showed a significant F ratio ($p<0.10$), we used the 5% L.S.D. to compare the Actara® treatments to untreated and standard controls.

Results

First harvest

At the first plant assessment, all the pesticide treatments, except for the lowest rate of Actara®, had significantly fewer potential storage roots than the untreated control (Table 3b.1). There was no difference in numbers or percentages of storage roots affected by sweetpotato weevil between the treatments, the latter ranging from 0-10% across the experiment. The weights of sweetpotato storage roots per plant told the same story (Table 3b.2). There was virtually no weevil damage in the soil-applied Actara® treatment.

Table 3b.1: Impacts of pesticide application on the average numbers of sweetpotato storage roots per plant at 57 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged	Percentage of roots damaged
Untreated control	3.05 b*	2.80 a	0.15 a	3.8 a
Standard (Talstar®)	1.70 a	1.48 a	0.15 a	5.4 a
Actara® low	2.05 ab	1.92 ab	0.10 a	3.9 a
Actara® medium	1.58 a	1.25 a	0.21 a	9.2 a
Actara® high	1.38 a	1.10 a	0.11 a	4.2 a
Actara® soil applied pre-plant	1.72 a	1.70 a	0.02 a	0.6 a
F ratio probability	0.053	0.045	0.641	0.748
L.S.D. (5%)	1.03	1.04	n.a.	n.a.
* values in the same column followed by the same letter are not significantly different				

Table 3b.2: Impacts of pesticide application on the average weights of sweetpotato storage roots (g) per plant at 57 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged
Untreated control	190 b	171 b	17 a
Standard (Talstar®)	97 a	88 a	8 a
Actara® low	117 ab	111 ab	5 a
Actara® medium	116 a	92 a	21 a
Actara® high	68 a	48 a	17 a
Actara® soil applied pre-plant	100 a	100 a	0 a
F ratio probability	0.073	0.058	0.415
L.S.D. (5%)	73	69	n.a.
* values in the same column followed by the same letter are not significantly different			

Second assessment

By the second assessment date, nearly 2 months after the initial assessment, the standard Talstar® treatment, as well as the highest rate drip application and soil applied Actara® treatments, still had fewer storage roots than the untreated control.

However, by this stage there was much evidence of sweetpotato weevil infestation in the crop. Only the standard Talstar® treatment significantly reduced the numbers and proportion of sweetpotato storage roots damaged by weevil (Table 3b.3). Similarly, this standard treatment had the greatest number of clean roots per plant, although the only significant reduction in clean roots was in the highest rate of drip-applied Actara®. Both the standard Talstar® and soil-applied Actara® treatments had no weevil tunnelling in the sweetpotato tops.

Table 3b.3: Impacts of pesticide application on the average numbers of sweetpotato storage roots per plant at 118 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged	Percentage of roots damaged	Percentage of stems weevil infested
Untreated control	3.32 c*	1.98 b	1.10 b	32.6 b	60 b
Standard (Talstar®)	2.48 b	2.38 b	0.08 a	2.7 a	0 a
Actara® low	2.75 bc	2.25 b	0.43 b	15.6 b	10 a
Actara® medium	2.58 bc	1.92 b	0.64 b	25.3 b	35 ab
Actara® high	1.62 a	0.88 a	0.57 b	35.0 b	25 ab
Actara® soil applied pre-plant	2.20 ab	1.65 ab	0.51 b	23.5 b	0 a
F ratio probability	0.011	0.027	0.003	0.004	0.034
L.S.D. (5%)	0.79	0.88	L.T.**	L.T.	40
* values in the same column followed by the same letter are not significantly different					
** data were back transformed after analysis – LSD relevant to transformed data, therefore unrepresented					

At this second assessment, the total weights of storage roots in all the pesticide treatments were significantly less than the untreated control plots. The standard Talstar® treatment virtually eliminated the presence of weevil damage in the roots, meaning that treatment had the greatest weight of clean roots. There was a non-significant but consistent trend for the Actara® treatments to have less weevil damage than the untreated control, particularly when soil-applied pre-plant. However, because there were fewer overall sweetpotato storage roots in the plots treated with high rates of Actara®, their production of clean storage roots was significantly less than the Talstar® standard.

Table 3b.4: Impacts of pesticide application on the average weights of sweetpotato storage roots (g) per plant at 118 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged
Untreated control	277 b*	118 bc	138 c
Standard (Talstar®)	177 a	166 c	10 a
Actara® low	173 a	134 bc	34 ab
Actara® medium	182 a	115 bc	65 bc
Actara® high	112 a	39 a	62 bc
Actara® soil applied pre-plant	138 a	85 ab	50 a
F ratio probability	0.012	0.008	0.015
L.S.D. (5%)	79	61	L.T.**
* values in the same column followed by the same letter are not significantly different ** data were back transformed after analysis – LSD relevant to transformed data, therefore unrepresented			

Final assessment

By the time of commercial harvest, 144 days after planting, sweetpotato weevil had impacted the whole experiment. Table 3b.5 shows the percentages of damaged roots had climbed in the pesticide plots, although it was still trending lowest in the standard Talstar® treatment. By this stage the numbers and weights of clean roots per plant were similar across the whole experiment (Tables 3b.5 and 3b.6).

Table 3b.5: Impacts of pesticide application on the average numbers of sweetpotato storage roots per plant at 144 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged	Percentage of roots damaged	Percentage of stems weevil infested
Untreated control	2.85 a*	1.90 a	0.95 a	33.2 a	35 a
Standard (Talstar®)	1.95 a	1.82 a	0.12 a	6.3 a	10 a
Actara® low	2.12 a	1.45 a	0.68 a	31.4 a	25 a
Actara® medium	2.48 a	1.58 a	0.90 a	36.0 a	25 a
Actara® high	2.05 a	1.42 a	0.62 a	33.7 a	45 a
Actara® soil applied pre-plant	2.42 a	1.68 a	0.75 a	30.8 a	55 a
F ratio probability	0.133	0.929	0.346	0.502	0.143
L.S.D. (5%)	n.a.	n.a.	n.a.	n.a.	n.a.
* values in the same column followed by the same letter are not significantly different					

Table 3b.6: Impacts of pesticide application on the average weights of sweetpotato storage roots (g) per plant at 144 days after planting (n = 10 sweetpotato plants with variable numbers of storage roots)

Treatment	Total	Clean	Weevil damaged
Untreated control	240 a	146 a	84 a
Standard (Talstar®)	164 a	148 a	16 a
Actara® low	152 a	104 a	49 a
Actara® medium	203 a	135 a	68 a
Actara® high	152 a	102 a	50 a
Actara® soil applied pre-plant	182 a	112 a	71 a
F ratio probability	0.216	0.851	0.345
L.S.D. (5%)	n.a.	n.a.	n.a.
* values in the same column followed by the same letter are not significantly different			

The high weevil populations certainly challenged the efficacy of the insecticides in this field experiment. The rainfall events in December 2010 may also have reduced the longer-term effectiveness of the pesticides, particularly the Actara® treatments, which were only applied once early in the life of the sweetpotato crop. The standard Talstar® treatment gave the most consistent, sustained control of weevil infestation in the plant tops and weevil damage to storage roots. Although perhaps initially effective (particularly the pre-plant, soil applied treatment), the Actara® pesticide was significantly less effective than the standard treatment at preventing weevil damage by the second assessment, and by commercial harvest conferred no advantages.

All pesticide treatments seemed to reduce the initiation and development of sweetpotato storage roots (see the first assessment, when weevil damage was minor) compared to the untreated control. This deleterious comparison slowly dissipated as the crop grew, however this was probably due to increasing levels of weevil damage in the untreated plots, masking their initial storage root advantage.

Discussion

There were indications in the field experiment that initial development of sweetpotato storage roots might be adversely affected by applications of Talstar® or Actara®. Beauregard commercially commonly achieves upwards of three storage roots per node when Talstar® is routinely being applied. The initial white adventitious roots formed on the planting vines inter-nodal areas physiologically change to become storage roots at approximately 21-28 days after planting. This is an important consideration in the commercial production of sweetpotato. Many factors can disrupt the plants ability to initiate these storage roots such as water, plant available nutrients, nematodes, temperature and plant viruses. An average of 2.85 storage roots recorded per plant (or less then one storage root per node as all plant material is standardised in these trials to have three nodes under the ground) at commercial harvest across the untreated control plots would suggest that there were some other significant factors interfering with the normal development of storage roots at this trial site.

The levels of sweetpotato weevil control achieved by Actara® applied through drip irrigation were minimal, even at the highest rate of 250 g/ha. Pre-plant soil incorporation of 1 000 g/ha of Actara® gave better initial control of weevils in plant tops, but was no better at preventing weevil damage to storage roots.

In summary, this experimental work found that commercial application rates of Actara® did not successfully control sweetpotato weevil feeding or damage to storage roots, and was significantly worse than the current commercial practice using bifenthrin. At this stage, other chemistry and management practices look more promising for further research and commercialisation.

c) Report on the efficacy of various soil drench treatments that provide plant systemic protection against sweetpotato weevil *(Cylas formicarius)* adult feeding injury on sweetpotato plant parts in replicated pot trial experiments.

Introduction

This report has been compiled in collaboration with Craig Henderson of Agri-Science Queensland, Department of Agriculture, Fisheries and Forestry, based on experimental work conducted by Russell McCrystal, formerly of the same organisation. Russell McCrystal undertook this work in collaboration with ASPG Inc lead HAL project VG09052 and Syngenta Australia. Both Craig Henderson (QDAFF) and Ken McKee (Syngenta Australia) have agreed for this report to be included in VG09052 final report.

This report details experimental pot trial work conducted to investigate the activity of chemical compounds that can be applied as a soil drench to the plant root system and be taken up into the above ground plant parts, which may repel the feeding activity of the adult sweetpotato weevil.

Both the adult male and female sweetpotato weevil feed on the above ground plant parts of the sweetpotato plant. This damage presents as small excavations or pits on plant stems, petioles and underside of leaves. The adult female sweetpotato weevil lays her eggs in these excavated feeding injury holes or pits and then caps them with a black faecal deposit. The egg hatches and the immature larval development period takes place entirely within the host plant material, emerging approximately 30 days later as a mature active sweetpotato weevil. A significant reduction in adult weevil feeding injury could therefore lead to a significant reduction in egg lay on the host crop.

Reducing the number of egg laying sites using such an approach would potentially lead to a reduction in subsequent generations of the pest emerging from the host plant material in a way that is non-disruptive to other beneficial organisms inhabiting the sweetpotato crop. Currently the only form of commercial control available is the routine (4 weekly) foliar application of broad-spectrum insecticides. It is well known that if this pest goes untreated in commercial sweetpotato crops it can significantly reduce marketable yields within a 120-day crop development period.

In two of the pot experiments, 250 g/ha of Actara® applied as a soil drench did not reduce weevil feeding on sweetpotato tops (compared to untreated controls). In the third pot experiment, that highest Actara® rate did slightly reduce weevil feeding, but not to a commercially acceptable level.

In summary, this experimental work found that certain soil drenches successfully reduced sweetpotato weevil feeding on developing sweetpotato above ground plant parts. Further investigations should be undertaken that quantify the potential impact on subsequent larval numbers and developmental rates of the pest by reducing adult feeding damage using such plant systemic compounds. Further investigations would then need to be undertaken for proposed commercial uses of such chemical compounds applied using shallow, sub-surface drip irrigation in sweetpotato production systems at various stages of the crop developmental period.

Materials and Methods

Three pot experiments were conducted; two in November/December 2010, and another in July/August 2011. Each experiment comprised 5 treatments, replicated 5 times in a completely randomised design. Each 25 cm diameter pot was filled with standard potting mix and basal fertiliser, and planted with a 30 cm, standardised virus-free sweetpotato cutting (cv. Beauregard). Plants were grown for two weeks to establish a root system before treatments were applied. The treatments were:

1. **Untreated control**. No pesticides applied for weevil management.

2. **DuPont compound X**. Soil drench addition to pot, applying the equivalent of 200 g/ha active constituent of DuPont X at 14 days after planting (DAP).

3. **Actara® medium**. Soil drench addition to pot, applying the equivalent of 188 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 14 DAP.

4. **Actara® high**. Soil drench addition to pot, applying the equivalent of 250 g/ha of Actara® (250 g/kg thiamethoxam WDG formulation) at 14 DAP.

5. **Bayer compound X**. Soil drench addition to pot, applying the equivalent of 350 g/ha active constituent of Bayer X at 14 DAP **(pot experiment 1 & 2). Bayer compound Y.** Soil drench addition to pot, applying the equivalent of 200 g/ha active constituent of Bayer compound Y at 14 DAP **(pot experiment 3).**

One day after the soil drenches were applied, a cage containing 10 unsexed weevils was placed over each pot. After 10 days of potential feeding opportunity, the plant tops were assessed for evidence of weevil feeding.

For the first two pot experiments, the base of the sweetpotato plant, and random locations at 4 points on the mid-upper stem of the plant were examined for feeding damage, giving 5 assessments per pot. Each assessment location was given a score:

1 for no evidence of feeding; 2 for any evidence of feeding, and 3 for substantial feeding damage. The 4 stem ratings were averaged; giving one base rating and one stem rating per pot.

For the third experiment, plants were rated (same scale) for feeding damage to the base of the main stem, mid stem leaves (upper and lower surfaces and petioles), and upper leaves. Plants were given an overall damage rating score, and the total length of the main stem was measured.

Results

In the first pot trial significant reductions in sweetpotato weevil feeding damage were found when soil drenching 200 g/ha equivalent of DuPont compound X in comparison to the untreated control (Table 3c.1). In the second pot trial a reduction in sweetpotato weevil feeding damage on plant parts were detected when the soil drench of 200 g/ha equivalent of DuPont X was applied, however the reduction was not significant in comparison to the untreated control.

In the first two pot trials, soil drenching with either 188 and 250 g/ha equivalent of Actara® or 350 g/ha equivalent of Bayer compound X did not significantly reduce sweetpotato weevil feeding damage to the sweetpotato plants in comparison to the untreated control (Table 3c.1).

Table 3c.1: Impacts of pesticide application on sweetpotato weevil feeding activity on sweetpotato cuttings 11 days after treatment.

Treatment	Experiment 1		Experiment 2	
	Base damage	Stem damage	Base damage	Stem damage
Untreated control	2.80 a*	2.95 a	2.4	2.6
DuPont X	1.40 b	1.60 b	2.00	2.05
Actara® medium	2.20 ab	2.35 ab	2.00	2.30
Actara® high	2.00 ab	2.55 a	2.20	2.5
Bayer X	2.80 a	3.00 a	2.00	2.3
F ratio probability	0.022	0.009	0.896	0.691
L.S.D. (5%)	0.92	0.78	n.s.	n.s.

* values in the same column followed by the same letter are not significantly different.
Rating scores: 1 - no evidence of feeding; 2 - any evidence of feeding, and 3 - substantial feeding damage.

In the third pot experiment, there were no adverse effects of any soil drench treatments on sweetpotato vine growth (Table 3c.2).

Overall weevil feeding damage: In the third pot experiment significant reductions in overall sweetpotato weevil feeding damage were again found when soil drenching 200 g/ha equivalent of DuPont compound X, 200 g/ha equivalent of Bayer compound Y and the high rate of 250 g/ha equivalent Actara® in comparison to the untreated control (Table 3c.2). The DuPont compound did not provide a significantly greater reduction in overall feeding damage in comparison to Bayer compound Y, but did provide a significantly greater reduction in comparison to the high Actara® treatment.

Main stem feeding damage: Significant reductions in adult weevil feeding damage to the main stem area of sweetpotato plant were found when soil drenching 200 g/ha equivalent of Bayer compound Y, 200 g/ha equivalent of DuPont compound X, and the high rate of 250 g/ha equivalent Actara® in comparison to the untreated control (Table 3c.2). The Bayer compound did not provide a significantly greater reduction in main stem damage in comparison to DuPont compound X, but it did provide a greater reduction than the high Actara® treatment.

Petiole feeding damage: Significant reductions in adult weevil feeding injury damage to the petioles of the sweetpotato plant were found when soil drenching 200 g/ha equivalent of DuPont compound X and 200 g/ha equivalent of Bayer compound Y in comparison to the untreated control (Table 3c.2). The DuPont compound did not provide a significantly greater reduction in petiole feeding damage in comparison to the Bayer compound.

Under-leaf feeding damage: Significant reductions in adult weevil feeding injury damage to the underside of the leaves of the sweetpotato plant were found when soil drenching 200 g/ha equivalent of DuPont compound X in comparison to all other treatments (Table 3c.2.) The soil drench treatments of 200 g/ha equivalent of Bayer compound Y and the high rate of 250 g/ha equivalent Actara® provided a significant reduction in feeding damage to the underside of leaves in comparison to the untreated control (Table 3c.2).

Table 3c.2: Impacts of pesticide application on sweetpotato weevil feeding activity on sweetpotato cuttings 11 days after treatment.

Treatment	Vine length (cm)	Overall damage	Mainstem damage	Petiole	Underleaf damage
Untreated control	27.8	3.00 a	3.00 a	3.00 a	3.00 a
Dupont X	32.8	1.60 d	1.70 bc	1.60 c	1.20 c
Actara® medium	39.4	2.50 ab	2.30 ab	2.70 ab	2.50 ab
Actara® high	38.4	2.30 bc	2.10 b	2.30 abc	2.20 b
Bayer Y	38.0	1.70 cd	1.50 c	2.20 bc	1.90 b
F ratio probability	0.313	0.002	0.003	0.011	0.001
L.S.D. (5%)	n.s.	0.679	0.710	0.76	0.68

* values in the same column followed by the same letter are not significantly different.
Rating scores: 1 - no evidence of feeding; 2 - any evidence of feeding, and 3 - substantial feeding damage.

Conclusions

Phytotoxic effects of Actara® on sweetpotato vine growth were not observed in the pot experiments.

In first two pot experiments, 250 g/ha of Actara® applied as a soil drench did not reduce weevil feeding on sweetpotato tops (compared to untreated controls). In the third pot experiment, that highest Actara® rate did slightly reduce weevil feeding, but not to the same degree as DuPont compound X and Bayer compound Y.

This work gives some hope that in the future industry could potentially move away from its dependence on the routine foliar applications of bifenthrin and chlopyrifos to control sweetpotato weevil during the crop development period of commercial sweetpotato farming systems. This would be a strategic outcome allowing the industry to utilise beneficial organisms in the crop to manage other insect pests such as aphids and whitefly. Further investigations should be made to quantify the impact of such compounds on the number of egg laying sites on sweetpotato plants and the subsequent developmental rates of larvae within the sweetpotato plant material.

Further investigations also need to be undertaken in order to demonstrate field efficacy of these chemical compounds when applied using shallow, sub-surface drip irrigation in sweetpotato production systems at various stages of the crop developmental period.

d) Report on the varietal tolerances of imported United States germplasm under Australian conditions.

As part of project VG05037, 'Better management of sweetpotato soil insects', the varieties Sumor (white), Regal (gold) and Excel (gold) were imported from the United States of America (USA) germplasm collection due to their reported higher tolerance levels to root knot nematode, sweetpotato weevil and wireworm in comparison to the currently commercially grown varieties in Australia. Thanks to the efforts of VG09009 project leader Sandra Dennien (QDAFF) these varieties made it out of quarantine and were available for field evaluation in sweetpotato production regions during this project period. VG09052 worked closely with Sandra Dennien (QDAFF) as project leader of VG09009 throughout 2010 to 2012 to establish and assess varietal trials in the three major sweetpotato production regions. These trials included Sumor, Regal and Excel for assessment. In 2012, projects VG09009 and VG09052 collaborated to conduct joint field days at the Bundaberg and Cudgen varietal assessment sites at commercial harvest. The aim of these events was to review varietal performance and gather grower comments and perspective on these cultivars. As a result of these activities these three varieties were not deemed suitable for commercial purposes and therefore were no longer pursued. The undesirable characteristics such as poor skin colouring, poor flesh colouring, high sap contents and poor total yields in comparison to the industry standards meant they were culled from ongoing commercialisation. The performance of these varieties has been extensively reported on in HAL project VG09009 final report 'Evaluating sweetpotato varieties to meet market needs' (Wolfenden *et al.* 2014)

Throughout the 2010 to 2012 period two further varieties imported from the USA that showed commercial potential with increased root knot nematode tolerances under Australian field conditions were Bienville and Evangeline, as documented in VG09009 final report (Wolfenden *et al.* 2014). An observational pot trial established on 9th August 2011 grew out Bienville, Evangeline and Beauregard in soils infested with root knot nematodes collected from Bundaberg Research Facility. A total of two pots per variety were established with two plants of each variety planted in each pot. At 100 DAP soils from each of the pots were collected and sent for root knot nematode count analysis and plant roots were washed and visually assessed for presence of galling (Figures 3d.1, 3d.2 and 3d.3).

Beauregard had large galls present on both the adventitious roots and storage roots. The mean soil count across the two Beauregard pots was 185 root knot nematodes per 200 ml soil solution. The Beauregard adventitious root mass was smaller and had more black/brown necrotic areas on the roots in comparison to Bienville and Evangeline.

Bienville had no galls visually detectable on the storage roots and only a few galls present on the adventitious roots. No black/brown necrotic areas on the adventitious roots were noted. Root knot nematodes were not at detectable levels in either of the two pots for Bienville.

Evangeline had no galls detectable on the storage roots. Galls had formed on the adventitious roots to a greater extent than Bienville but not to the same extent as

Beauregard. The mean root knot nematode soil counts for the two pots of Bienville was eight.

These two imported varieties showed promising tolerance to root knot nematodes. Further work to test this tolerance under field conditions is warranted, and their inclusion in a breeding program to develop nematode resistant varieties suitable for Australian conditions could be considered.

Figure 3d.1: Beauregard root mass at 100 days after planting. Mean soil count of root knot nematodes for the two pots was 185 per 200 ml soil.

Figure 3d.2: Evangeline root mass at 100 days after planting. Mean soil count of root knot nematodes for the two pots was eight per 200 ml soil.

Figure 3d.3 Bienville root mass at 100 days after planting. Mean soil count of root knot nematodes for the two pots was zero per 200 ml soil.

e) Screening efficacy trial of DuPont chemical compound X applied through the drip irrigation system to control root knot nematode in the sweetpotato production system.

Introduction

This section reports on the efficacy testing of DuPont compound X applied at several rates against root-knot nematodes on the sweetpotato variety Beauregard. While the identity of DuPont compound X has been kept commercial-in-confidence, it supposedly has nematicidal properties and so was worthy of testing in this research program. The known nematicide Vydate® L was included in the trial for comparison as a positive control.

The field experiment was conducted at a grower's property near Bundaberg, Queensland, from September 2012 to February 2013, i.e. during spring and summer. The Bundaberg district (southeast Queensland) is the dominant sweetpotato production area in Australia. The highest risk potential for root knot nematode damage to roots occurs during the growing period from spring to the end of autumn.

Materials and methods

The field experiment was a randomised complete block design with eight treatments and four replicates (Table 3e.1). Plots were three rows wide by 15 m long. The middle row was the datum row and either side was a buffer row.

The treatments (Table 3e.2) were applied into the sub-surface drip system with a water powered dosing machine, supplied by Netafim, called a Dosatron D45 RE 3. The Dosatron was installed directly into the water supply line which enabled delivery of the treatments at a constant dosing ratio in proportion to the flow required to service the T-Tape sub-surface drip system. The T-tape used was Model 508-20-500. Emitter spacing was 0.2 m delivering 1 litre per hour of water at 70 kpa. Pressure control valves were used to ensure pressure and flow was maintained during the treatment delivery time.

The depth at which the test compounds were delivered to the root system was managed through the use of Full Stops. Full Stops are a wetting front detection device. Two Full Stops were placed in treatment 2 at 20 cm and 30 cm below the soils surface. Once the Full Stop at 20 cm detected the wetting front, test compounds were injected through the sub-surface drip system for approximately 5 minutes. Irrigation continued for a further 10 minutes after the completion of the treatment injection. The Full Stop at 30 cm below the soil surface would then detect the wetting front, confirming the delivery of the chemical to the sweetpotato root system.

The trial site was sampled at planting for root knot nematode by collecting soil samples randomly across the trial area. The samples were sent to QLD DAFF for root knot nematodes to be counted. The numbers present were deemed to be at sufficient levels to provide high infestation over the life of the crop (Table 3e.3). The untreated plots were sampled again at the end of the trial to assess any changes in numbers over the duration of the trial.

Sampling of sweetpotato roots was conducted on four occasions during the life of the field trial, at 69 days after planting (DAP), 90 DAP, 119 DAP and 147 DAP. Plots were sub-sampled by removing five plants from the datum row of the plot at each time of sampling. To minimise plant disruption in the plot, a buffer of two plants was maintained between each sub-sample. The samples were then washed and visually assessed for root knot nematode infestation, counted and weighed. The assessment consisted of three grades based on levels of commercial marketability (Table 3e.4). At commercial harvest (147 DAP) the sweetpotato roots were also visually assessed for wireworm and sweetpotato weevil feeding injury.

Key dates of key activities undertaken at the Bundaberg trial site:

21 September 2012	Planted trial	
28 September 2012	Injected treatments 1, 2, 3, 4, 5, 6 & 7	
12 October 2012	Injected treatment 7	
26 October 2012	Injected treatment 7	
31 October 2012	Injected treatments 5 & 6	(39 DAP)
9 November 2012	Injected treatment 7	
28 November 2012	First harvest Injected treatment 7	(69 DAP)
19 December 2012	Second sample harvest	(90 DAP)
17 January 2013	Third sample harvest	(119 DAP)
14 February 2013	Commercial harvest	(147 DAP)

Analyses of variance were conducted on the average counts and weights of storage roots assessed per plot at each of the harvests. Genstat Release 14.2 was used for all analyses.

Table 3e.1: Trial layout in the field.

Plot	Replicate	Treatment
1	1	3
2	1	6
3	1	4
4	1	1
5	1	5
6	1	7
7	1	2
8	1	8
9	2	4
10	2	3
11	2	1
12	2	6
13	2	5
14	2	8
15	2	2
16	2	7
17	3	1
18	3	7
19	3	4
20	3	6
21	3	5
22	3	8
23	3	3
24	3	2
25	4	1
26	4	3
27	4	4
28	4	2
29	4	7
30	4	8
31	4	5
32	4	6

Table 3e.2: Treatments used in the trial.

Treatment	Delivery system	Total rate of product /ha	Application regime
1. DuPont X	Sub-surface drip	1 kg	Single application at planting
2. DuPont X	Sub-surface drip	2 kg	Single application at planting
3. DuPont X	Sub-surface drip	3 kg	Single application at planting
4. DuPont X	Sub-surface drip	4 kg	Single application at planting
5. DuPont X	Sub-surface drip	2 kg	1 kg at planting + 1 kg at 30 days after initial application
6. DuPont X	Sub-surface drip	3 kg	2 kg at planting + 1 kg at 30 days after initial application
7. Vydate® L	Sub-surface drip	26 L/ha	18 L/ha at planting followed by four applications of 2 L/ha every 14 days after initial application
8. Untreated control	–	–	–

Table 3e.3: List of plant parasitic nematodes and the numbers present in 200 mL of soil from each across the trial site prior to planting September 2012 and at commercial harvest March 2013.

Sample areas	Date	*Plant parasitic nematodes/200 mL soil (corrected for extraction efficiency)			
		Root knot *Meloidogyne* sp.	Reniform *Rotylenchuius parvus*	Lesion *Pratylenchus* sp.	Spiral *Helicotylenchus dihystera*
Entire trial area	21/09/12	7	0	2	41
Row8/R1 UTC	28/03/13	2453	32	0	450
Row14/R 2 UTC	28/03/13	780	113	0	465
Row22/R 3 UTC	28/03/13	990	126	0	171
Row30/R 4 UTC	28/03/13	0	11	0	92
*No Reniform *Rotylenchuis reniformus*, Ring *Criconemelta sp*., Stunt *Tylenchorhynchus dihystera*, or Stubby *Paratrichodorus minor* plant parasitic nematodes detected in these samples.					

Table 3e.4: The commercial assessment criteria (Images of these criteria are shown in figures 2.1 – 2.4 of chapter 2).

Commercial grade	Infestation level	Category
First grade	No visual presence of root knot nematode damage	**1**
Second grade	Root knot nematode damage visually present Defects to skin included: - pimples - large eyes	**2**
Unmarketable	Root knot nematode damage visually present Defects to skin included: - galling - cracking - pinched in ends	**3**

Results

First harvest (69 DAP)

Minimal root knot nematode infestation was visually detected on storage roots from any treatment plots at 69 DAP (Table 3e.5). Very low numbers of second grade roots were recorded and no unmarketable roots were found. There were no significant differences between the number of storage roots per plot or the weight of storage roots per plot between treatments in either grade.

Table 3e.5: Results presented are the average count and weight of storage roots assessed per plot at 69 DAP.

Treatments	First grade (No visual presence of root knot nematode damage)		Second grade (root knot nematode damage visually present)	
	Counts	Weight (kg)	Counts	Weight (kg)
	n.s.	n.s.	n.s.	n.s.
1. DuPont X	14.5	0.985	1.75	0.375
2. DuPont X	13.75	1.111	0.75	0.082
3. DuPont X	14.25	1.072	1.25	0.17
4. DuPont X	19.25	1.180	1.00	0.065
5. DuPont X	14.5	0.975	3.75	0.365
6. DuPont X	14.5	0.935	2.00	0.215
7. Vydate® L	15.75	0.980	1.00	0.230
8. Untreated control	15.5	1.235	1.25	0.112

n.s. indicates no significant difference between treatments.

Second harvest (90 DAP)

Minimal root knot nematode damage was visually detected on storage roots from any treatment plots at 90 DAP (Table 3e.6). No unmarketable roots were recorded.

Table 3e.6: Results presented are the average count and weight of first grade and second grade storage roots assessed per plot at 90 DAP.

Treatments	First grade (No visual presence of root knot nematode damage)		Second grade (root knot nematode damage visually present)	
	Counts	Weight (kg)	Counts	Weight (kg)
	n.s.	n.s.	n.s.	n.s.
1. DuPont X	18.5	4.66	1	1.08
2. DuPont X	17.75	4.97	0	0.00
3. DuPont X	22.00	5.33	0	0.00
4. DuPont X	16.75	4.63	0.25	0.49
5. DuPont X	20.00	4.97	0	0.00
6. DuPont X	22.00	5.06	0	0.00
7. Vydate® L	20.75	5.51	0	0.00
8. Untreated control (UTC)	18.75	4.95	0.50	0.45

n.s. indicates no significant difference between treatments

Third harvest (119 DAP)
Root-knot nematode damage was visually detected on sweetpotato roots at 119 DAP as pimples and enlarged eyes (second grade). There were no significant differences between treatments in the number of storage roots in either the first grade or second grade categories (Table 3e.7). No unmarketable roots were recorded.

Table 3e.7: Results presented are the average count and weight of first grade and second grade storage roots assessed per plot at 119 DAP.

Treatments	First grade (No visual presence of root knot nematode damage)		Second grade (root knot nematode damage visually present)	
	Counts	Weight (kg)	Counts	Weight (kg)
	n.s.	n.s.	n.s.	n.s.
1. DuPont X	21.0	9.22	3.25	2.93
2. DuPont X	21.00	8.29	2.00	1.67
3. DuPont X	16.50	7.29	3.75	3.48
4. DuPont X	16.00	8.26	1.50	2.56
5. DuPont X	17.25	8.54	3.25	4.30
6. DuPont X	17.25	7.80	2.25	2.35
7. Vydate L	19.75	9.79	2.00	2.57
8. Untreated control	19.25	8.50	1.75	1.71

n.s. indicates no significant difference between treatments

Commercial harvest (147 DAP)
At commercial and final harvest no unmarketable sweetpotato roots were recorded. Root-knot nematode infestation was visually detected on sweetpotato as pimples and enlarged eyes (second grade). There were no significant differences between treatments in the number of storage roots in either the first grade or second grade categories (Table 3e.8).

At final harvest, sweetpotato roots were also assessed for the presence of wireworm and sweetpotato weevil feeding injury.

Wireworm feeding injury was visually detected on sweetpotato roots (Table 3e.9). Significant differences between treatments were detected for numbers and weights of storage roots in the second and unmarketable categories.

Adult and larval sweetpotato weevil feeding injury was visually detected on sweetpotato roots. There were no significant differences between treatments in the number of storage roots in either of the three assessment categories (Table 3e.10).

Table 3e.8: Average count and weight of storage roots assessed per plot for root knot nematode infestation at commercial harvest (147 DAP).

Treatments	First grade (no visual presence of root knot nematode damage)		Second grade (root knot nematode damage visually present)	
	Counts	Weight (kg)	Counts	Weight (kg)
	n.s.	n.s.	n.s.	n.s.
1. DuPont X	8.25	4.87	11.00	7.50
2. DuPont X	9.75	5.08	8.75	5.86
3. DuPont X	11.40	5.06	13.25	7.05
4. DuPont X	8.50	5.48	10.00	6.45
5. DuPont X	11.75	6.38	8.25	5.46
6. DuPont X	7.50	3.77	14.75	7.18
7. Vydate® L	10.00	5.56	10.75	6.77
8. Untreated control	10.75	4.79	8	5.70

n.s. indicates no significant difference between treatments

Table 3e.9: Results presented are the average count and weight of storage roots assessed per plot for wireworm feeding injury at 147 DAP.

Treatment	First grade (No wireworm feeding injury)		Second grade (Three or fewer wireworm feeding holes)		Third grade (More than three wireworm feeding holes)	
	Counts	Weight (kg)	Count	Weight (kg)	Count	Weight (kg)
1. DuPont X	10.75	5.76	8.50 d*	5.63 c	2.25 ac	3.49 abc
2. DuPont X	11.75	6.51	4.00 ab	3.12 ab	2.75 ac	2.67 ab
3. DuPont X	18.25	8.46	2.50 a	2.27 a	1.09 a	1.85 a
4. DuPont X	11.00	6.77	5.75 bcd	4.69 bc	4.40 acd	3.86 abcd
5. DuPont X	10.75	5.22	5.25 abc	4.30 bc	4.99 cd	4.78 bcd
6. DuPont X	14.75	6.45	5.00 abc	3.41 ab	6.90 d	5.60 cd
7. Vydate® L	12.75	6.37	4.75 abc	3.50 ab	5.96 cd	6.41 d
8. Untreated control	12.75	5.78	7.30 cd	4.44 bc	2.99 ac	3.33 abc
LSD (P<0.05)	n.s.	n.s.	3.204	1.704	3.796	2.708
* values in the same column followed by the same letter are not significantly different						

Table 3e.10: Results presented are the average count and weight of storage roots assessed per plot for sweetpotato weevil feeding injury at 147 DAP.

Treatment	First grade (No sweetpotato weevil feeding injury)		Second grade (Adult sweetpotato weevil feeding holes)		Third grade (Both adult sweetpotato weevil feeding holes and larval tunnelling in roots)	
	Counts	Weight (kg)	Count	Weight (kg)	Count	Weight (kg)
1. DuPont X	17.75	10.07	0.00	0.00	1.00	0.80
2. DuPont X	17.25	8.71	0.75	1.15	0.50	0.69
3. DuPont X	20.25	9.33	0.25	0.44	1.25	1.59
4. DuPont X	17.75	9.74	0.25	0.56	0.50	0.85
5. DuPont X	19.00	9.27	0.50	1.03	0.25	0.78
6. DuPont X	20.75	9.05	0.75	0.59	0.75	1.19
7. Vydate® L	19.75	10.22	0.27	0.32	0.75	1.38
8. Untreated control	19.25	8.50	0.75	1.21	0.00	0.00
LSD (P<0.05)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
n.s. indicates no significant difference between treatments						

Discussion

DuPont X compound demonstrated no adverse effects on the establishment and storage root development rates of the sweetpotato crop in comparison to the untreated control.

The presence of root knot nematodes was observed as galling on storage roots at the trial site location in the previously harvested sweetpotato crop of April and May 2012. Seven root knot nematodes were detected in the soil sample collected from across the trial site at planting (September 2012). There was an inability for this population of root knot nematodes to rapidly develop into damaging levels during the crop development period of 147 days. Root knot nematodes present in soils collected from untreated control plots at commercial harvest (147 DAP) ranged from zero to 2453. This site was also extensively flooded around 26th January 2012, which caused rots in some of the storage roots. This storage root loss may have also confounded the final results at commercial harvest.

Results for the industry standard nematicide treatment of Vydate® L showed little differences with root knot nematode infestation in comparison to the untreated control, indicating that populations were not adequately present. DuPont compound X should be further pursued by Australian Sweetpotato Growers Inc. in order to appropriately ascertain the activity of this product against root knot nematode in sweetpotato production systems. Due to the sweetpotato crop development period ranging from 120 – 260 plus days the sweetpotato industry needs to pursue crop protectants that can be applied both at planting and later in crop development periods in order to provide the protection required through to commercial harvest.

Results showed significant differences between the untreated control and a DuPont compound X, treatment but no clear rate response pattern was evident across the DuPont compound X treatment regime.

Sweetpotato weevil damage was evident at commercial harvest but in very low levels. Pest populations were likely to low to adequately test any activity of DuPont compound X against the sweetpotato weevil.

Chapter 4: Technology transfer

Methods used:

1. Field experiments
2. Pest Management Workshop series
3. Grower collaborator farming system trials
4. Grower participatory learning events/field walks
5. Media
6. Newsletter, grower publications and WOCIMS video
7. Farm visits
8. Australian Sweetpotato Growers Inc.
9. HAL VG05037 Milestone Reports

1. Field experiments

Of the six field experiments listed below, three were carried out on cooperating growers' properties. There was a scientific need to assess the efficacy of products at a number of soil types and production regions to obtain adequate and robust efficacy data. Apart from this obvious scientific need to work on cooperating grower properties, growers were personally involved in the design, implementation and interpretation of results. These lead growers became key drivers in the information transfer process.

1. Efficacy of fipronil applied through sub-surface drip at various crop development stages against wireworm. 2010 production season.
Place: Cudgen (NSW) grower's property.

2. Field efficacy of thiamethoxam applied through sub-surface drip at various crop development stages. Soil incorporated insecticides applied prior to planting against sweetpotato weevil. 2009 - 2010 production season.
Place: Bundaberg Research Facility (QLD).

3. Field efficacy of thiamethoxam applied through sub-surface drip at various crop development stages. Soil incorporated insecticides applied prior to planting against sweetpotato weevil. 2010 production season.
Place: Bundaberg Research Facility (QLD).

4. Series of pot experiments of thiamethoxam and other plant systemic chemical compounds applied via soil drench to sweetpotato plants against adult sweepotato weevil feeding injury. 2011 production season.
Place: Bundaberg Research Facility (QLD).

5. Efficacy of fipronil applied through sub-surface drip at various crop development stages against wireworm. 2011 production season.
Place: Bundaberg (QLD) grower's property.

6. Efficacy of trickle irrigation applied DuPont compound X against root knot nematode in sweetpotato. 2012 production season. Place: Bundaberg (QLD) grower's property.

2. Pest Management Workshop series

Improved awareness and understanding of sweetpotato pest management was achieved throughout the delivery of pest management workshops in the two major sweetpotato production regions of Australia. Dates, locations, content and grower participation data are presented in Chapter 1, Table 1.3.

3. Grower collaborator farming system trials

As a result of successfully engaging with a large proportion of the sweetpotato industry through the pest management workshop series, three lead growers were identified as willing to collaborate with project staff and implement large scale farming systems trials on their properties. The aim was to investigate strategies that would assist the development of a whole of crop integrated management approach to pest management in sweetpotato farming systems.

A. Grower commercial scale observational trial demonstrating improved delivery method techniques for chemigation and quantifying the efficacy of Vydate® L in conjunction with best bet cover crop management strategies. Matthew Prichard Cudgen, NSW production region, 2012 and 2013 production season

B. Grower commercial scale observational trial comparing the efficacy of Vydate® L and the soil incorporation of molasses at six rates in conjunction with best bet cover crop management strategies. Dave Holt, Rubyanna Rd, Bundaberg, QLD production region, 2012 and 2013 production seasons.

C. Grower commercial scale observational trials investigating the efficacy of fenamiphos soil incorporated prior to planting with best bet cover crop management strategies. Troy Prichard, Moore Park Rd, Bundaberg, QLD production region, 2011, 2012 and 2013 production seasons.

4. Grower participatory learning events/field walks and WOCIMS video publication

The project successfully engaged with a total number of 151 grower and industry stakeholder participants across the six participatory learning and field walk events (Table 4.1) The high attendance rates achieved at these events indicates that the project team was able to identify the key issues and drivers facing sweetpotato growers and industry stakeholders. Feedback received from participants at these events regularly reported that the work undertaken and information provided by VG09052 was relevant or highly relevant to their businesses.

Table 4.1: Project participation levels achieved at project VG09052 participatory field day events between April 2012 and June 2013.

Date	Venue	Topics covered	Number of participants	% Australian sweetpotato growers present	Key industry stakeholders present
April 2012	Site C) Prichard Farms (Moore Park)	Cover crop establishment and management. Pest population monitoring	34	41% of Aust industry 56% of QLD industry	Rural Advantage Ag supply store, Conag Agricultural Equipment. Australian Sweetpotato Seed, QLD DAFF researcher collaborators
July 2012	Site C) Prichard Farms (Moore Park) & Site B) Halt for Holts farms (Rubyanna)	Cover crop planting demonstration using Minimal till planter	15	18% Aust 24% QLD	Conag Agricultural Equipment,
Sept 2012	Site B) Halt for Holts farms (Rubyanna)	Cover crop management, nematicide Vs Molasses trial and pest monitoring	45	46% Aust 62% QLD	Pershouse Produce, David Russo Produce, Carter & Spencer Produce, Ads Up Engineering, CQ University, QLD DAFF research collaborators,

					Lindsay Rural, Norco Rural and Amcor
March 2013	Site A) Matthew Prichard farms (Cudgen NSW)	Best bet cover crop management and trickle applied nematicide	15	19% Aust 100% NSW	Lindsay Rural
May 2013	Site A) Matthew Prichard farms (Cudgen NSW)	Trickle applied nematicide & weevil scouting techniques	21	19% Aust 100% NSW	Linsday Rural, QLD DAFF research collaborators
June 2013	Bundaberg Bus tour to Site C) Prichard farms (Moore Park) & Site B) Halt for Holts farms (Rubyanna)	Best Bet cover crop management. Pest monitoring. Crop yield assessments	21	31% Aust 42% NSW	QLD DAFF research collaborators
		Total participants	151		

5. Media

The following print, radio, web and TV media activities were undertaken as part of the technology transfer process during the course of the project.

2010

- Good Fruit & Vegetables July 2010 Vol.22 No.1 ‘Sweet potato growers rise to soil pest challenge’.
- ABC Wide Bay Radio with rural reporter Scott Lamond, ‘Sweet potato research’. Broadcast 1 July 2010 on the Wide Bay Rural Report
- Farm Online QLD Country Life ‘Sweet potato growers rise to the soil pest challenge’ 16th June 2010

http://qcl.farmonline.com.au/news/state/horticulture/general/sweet-potato-growers-rise-to-soil-pest-challenge/1859920.aspx

2011

- ASPG Research Update; Industry mail out to all members, June 2011
- Good Fruit & Vegetables, Pest Management Workshops, August 2011
- Fruit & Vegetable News, Member Profile July 2011
- Spud Brother, Courier Mail QLD 23/4/11
- Producers show off QLD Delights, QLD Country Life 14/4/11
- Sweet colours in the kitchen, Cooloola Advertiser 26/4/11
- Sweet make over for the humble potato, Gladstone Observer 28/04/11
- QLD sweet potatoes gain new flavour, QLD Country Life 21/4/11
- Sweet science, Tablelands Advertiser, QLD 22/4/11
- A further 6 articles were published across various regional QLD newspapers with the same story.
- Troy Prichard and Russell McCrystal on ASPG Inc project work
    - Channel Seven Cairns 4/26/11
    - Channel Seven Townsville 4/26/11
    - Channel Seven Wide Bay 4/21/11
    - Channel Seven Rockhampton 4//20/11
- Troy Prichard and Russell McCrystal filmed an episode of 'OFF THE EATEN TRACK' in July with Chef Alistar Macleod. This programme showcased the sweetpotato industry and the science behind it. The show was telecast on Channel Seven QLD in December 2011 and then ran nationally on Seven in August 2012.
- Rodney Wolfenden, QLD Country Hour, ABC April 2011
- ABC Wide Bay, 4/20/2011, Scott Lamond, Rural reporter
- ABC Southern QLD Country Hour, 4/20/11, Jane Paterson
- 4GR Toowoomba QLD, 12/5/2011, Grahame Healy

Please note that a number of the above articles are available online on the publishers' websites

2012

- ASPG field day and AGM phone/email to all sweetpotato growers April 2012. (Over 45 growers from Central QLD, Northern NSW and Bundaberg attended.)
- Editor of Good Fruit & Vegetable Growers attended April event to develop a range of stories on VG09052 & VG09009
- Dean Akers, Darren Zunker and Russell McCrystal talking sweetpotato in Rural Weekly, Bundaberg News Mail 9 July 2012
- ASPG project updates & Field day advertisements at www.aspg .org.au
- Dean Akers, ABC Wide Bay Rural Report, 5 June 2012 (General sweetpotato industry news) http://www.abc.net.au/rural/regions/tropicalwidebay/
- Russell McCrystal, ABC Wide Bay Rural Report, 31 July 2012 (General sweetpotato industry news) http://www.abc.net.au/rural/regions/tropicalwidebay/

2013

- ABC Rural Website, 20th June, Rodney Wolfenden (General sweetpotato industry news)
- ABC Rural Website/Horticulture section/ Industry Links/ ASPG Inc included on Website menu
- ABC Wide Bay and QLD Country Hour. Rodney Wolfenden talking about sweetpotato growers participating in activities undertaken by project VG09052 (General sweetpotato industry news) Audio available: http://www.abc.net.au/rural/regions/tropicalwidebay/

6. Newsletters, grower publications and WOCIMS video.

Project activities and trial results were published in the June 2011 edition of Australian Sweetpotato Growers Inc. Research Update newsletter. The update is distributed to all Australian states with a distribution list to all ASPG Inc members.

A range of grower publications were prepared on topics including insect pest identification, insect pest life cycles and project research updates and were distributed as part of the Pest Management workshops undertaken throughout 2011. All attendees at these workshops received a copy of "Identification of insects, spiders and mites in vegetable crops, Workshop manual, Second edition" (Heisswolf *et al.* 2010a).

Research update publications were produced for each of the grower participatory learning events undertaken throughout 2012 and 2013, some of which included:

- Identification of adult sweetpotato weevil feeding injury on plant parts and sweetpotato weevil site survey 'What did we find below the soil's surface';
- Root knot nematode and molasses VS nematicide trail results undertaken on lead grower's property, Dave Holt, Rubyanna QLD;
- Root knot nematode soil count results for Grower participation site at Matthew Prichard's farm Cudgen NSW.

The major grower publication is the development of the whole-of-crop integrated management (WOCIMS) video documentary showcasing the major outcomes from the work undertaken with lead growers throughout 2012 and 2013. This has been successfully distributed to all sweetpotato growers on the ASPG Inc database. Due to the successful implementation of the grower collaborator farming system trials' participatory learning events and field walks, the project undertook the task to deliver project outcomes and findings using the communication format of video. Traditionally grower publications are written documents that highlight the key project findings and outcomes. Feedback sought from ASPG Inc members indicated that they were interested in utilising video as the format to deliver project findings and outcomes to industry, especially now that internet and mobile devices allow for rapid streaming of high quality video and audio files. The project team took the approach of utilising lead growers who facilitated the large scale farming system trials to share their insights into taking a whole-of-crop integrated management (WOCIMS) approach to better managing pests in their sweetpotato farming systems. The 17-

minute WOCIMS video documentary is hosted on VIMEO (Figure 4.1) and can be found at weblink: https://vimeo.com/92479777 (Password: VG09052). The complete transcript has been included and is presented in Table 4.2.

Figure 4.1: Sweetpotato whole of crop integrated pest management web video title page.

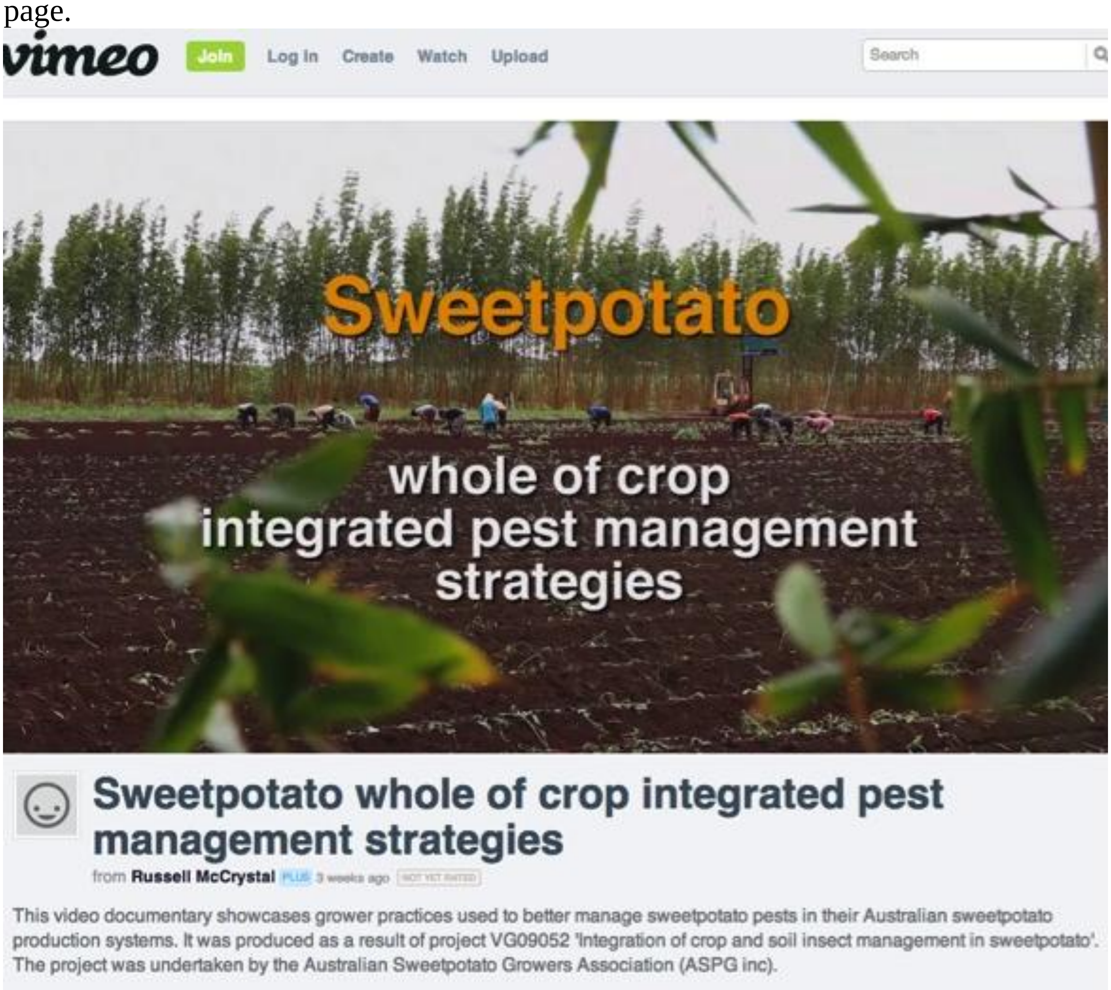

Table 4.2: Complete transcript of whole-of-crop integrated pest management strategies video publication including both description of video footage used and audio used in the production of the documentary. (VO = Voice over, Dean = Dean Akers, Dave = Dave Holt and Matt = Matthew Prichard)

Video	Audio
MONTAGE PLANTING	MUSIC VO The sweetpotato industry is one of Australia's fastest growing horticulture sectors. Over the past ten years more and more land has been committed to growing the crop with the industry's annual worth being estimated at one hundred million dollars farm gate.
TITLE: SWEETPOTATO WHOLE OF CROP INTEGRATED PEST MANAGEMENT STRATEGIES	MUSIC ENDS
VARIOUS SHOTS DIGGING CROP	VO But greater production has not necessarily resulted in an equivalent level of profitability, with many growers looking to achieve a better return on their investment. And like the classic Mexican Standoff in a TV Western, growers find themselves facing off against two opposing forces that seem determined to stop them achieving their goal.
CUSTOMERS AT FRUIT & VEGE STALL	VO On one hand, producers are confronted by the increasing demands of consumers. GRAB FROM DEAN 'As the market is so strong now on having all the fruit being the best possible sweetpotatoes we can grow, there's no room to move.’
DEAN ON CAMERA SUPER: DEAN AKERS GROWER/ASPG PROJECT LEADER BUNDABERG	GRAB FROM DEAN CONT. 'You've got to be always at the top of your game and always deliver 100% top quality and top yields.’ (45:07:00 - 45:22:00)
TRACTOR AND SPRAY RIG	VO On the other hand, the challenge is for sweetpotato growers to adopt more sustainable ‘clean-green’ practices.

TRACTOR AND SPRAY RIG CONT.	GRAB FROM DAVE ‘We’re currently coming under a lot of pressure from an environmental point of view with use of chemicals in sweetpotatoes.’
DAVE ON CAMERA SUPER: DAVID HOLT GROWER/ASPG PROJECT COLLABORATOR BUNDABERG	EDIT FUTHER GRAB FROM DAVE ‘We have only 2 chemicals available to us to treat nematodes in sweetpotatoes. One of them is under review at this time.’ {07:37:00 - 07:59:00)
WOMAN IN FRUIT & VEG STALL BUYING SWEETPOTATOES	VO It’s a 3 way standoff that causes many to wonder - who will be left the last man standing. MUSIC VO But it’s not the consumers or the environmental regulators that are the grower’s real enemy.
DEAN ON CAMERA	GRAB FROM DEAN ‘The 3 major pests that we are experiencing through the sweetpotato industry currently…
GRAPHIC: CROP PESTS	…are nematodes, sweet potato weevil and wireworm.’ (31:37:00 - 31:47 :00) VO The dilemma for growers is how to effectively deal with these pests while holding in tension the competing interests of the market place and the environment.
GRAPHIC: ASPG INC. LOGO & HORTICULTURE AUSTRALIA LOGO	VO Its a hard ask, but a 4 year research project by the Australian Sweetpotato Growers Association, and funded by Horticulture Australia set out to find a practical solution to this problem.
DEAN ON CAMERA	GRAB FROM DEAN 'The main reason for the project was to reduce the dependency we have on chemicals and also to bring out some better farming practices.’ (32:57:00 - 33:04:00)
VARIOUS STILL PHOTOS OF	VO

WORKSHOP	In the first phase of the project the ASPG ran a series of pest management workshops to arm growers with a better understanding of the major sweetpotato pests and their life cycles. Growers were also introduced to the methods available to monitor these pests in their farming systems.
DEAN ON CAMERA	GRAB FROM DEAN 'Overall we had participants of 88 growers that come on board over that time and that was a pretty good numbers for our industry that we thought were very, very high.' (38:54:00 - 39:05:00)
VARIOUS STILL PHOTOS OF DEMONSTRATION SITES	VO The second phase established three large-scale demonstration sites, managed by lead growers and collaborating researchers. These sites allowed innovations to be trialled under real farm conditions. GRAB FROM DEAN 'On the second stage of the project we had six field walks on farm and during this time we had 150 growers participate in these trials.' (40:15:00 - 40:27:00) Music ends
VARIOUS SHOTS OF DAVE HOLT DRIVING TRACTOR	VO Traditionally, the application of chemicals during the cropping period has been the only technique used to control pests. The field trials demonstrated how the focus can be shifted instead to managing pest populations between crops. The trials showed that in this way pest pressure can be significantly reduced prior to planting.
COVER CROP	VO Techniques successfully trialled included better cover crop planting and management…
MATT PRICHARD INSPECTING CROP	VO CONT. …plus a more refined delivery of chemicals during the growing period.

	GRAB FROM MATTHEW ‘Our focus on these techniques has resulted in reduced chemicals in the environment, zero crop residues,…’
MATTHEW ON CAMERA SUPER: MATTHEW PRICHARD GROWER/ASPG PROJECT COLLABORATOR CUDGEN	GRAB FROM MATTHEW CONT. ‘…more use of cultural techniques to reduce population pressures and also our main focus is to deliver a clean green product to the market place.’ (06:57:10:00 - 06:57:28:00)
DEAN ON CAMERA	GRAB FROM DEAN 'The positives to come out of these trials was that each grower then had the information to take back to their own farm and put this into practice in their own environment.’ (40:51:00 - 41:00:00)
VARIOUS SHOTS OF DAVE HOLT & MATT PRICHARD INSPECTING CROPS	MUSIC VO The following case studies illustrate how two growers have tackled the pest problem in their sweetpotato crops. While they specifically refer to the root knot nematode, the techniques they describe are effective in better managing the three major sweetpotato pests.
AERIALS OF FARM	VO CONT. David Holt and Matthew Prichard both led large scale demonstration trials on their properties and have now incorporated new strategies into their day-to-day farming operations.
PACKING SHED INTERIORS	VO CONT. As a result, they have found they are more consistently able to meet consumer demand for a high quality product. At the same time they have been able to reduce their environmental impact and best of all improve their bottom line.
GRAPHIC: WHOLE OF CROP STRATEGIES BETWEEN CROPPING PERIODS	MUSIC ENDS
VARIOUS SHOTS DAVE HOLT INSPECTING CROP	VO David Holt is a sweetpotato grower in Queensland's Bundaberg district with 100 hectares of red soil under cultivation.

	For him, root knot nematode has been the most difficult pest to manage in his crop.
DAVE ON CAMERA SUPER: DAVID HOLT GROWER/ASPG PROJECT COLLABORATOR BUNDABERG	GRAB FROM DAVE 'The damage that nematode can cause to sweetpotato can be as minor as the skin appearance...’
STILL PHOTOS OF SWEET POTATO WITH NEMATODE DAMAGE	GRAB FROM DAVE CONT ‘ ... having just like raised bumps over it and it can then also vary to the other end of the scale, it can end up at severe cracking of the sweetpotato.’ (23:39:13:00 - 23:39:31:00)……. 'If we market sweetpotatoes that have some forms of damage or minor damage even ... You seem to be downgraded fairly quickly ... and then if you have more severe damage it’s unsaleable within the market system. ' (23:40:46:00 - 23:41:12:00)
VARIOUS SHOTS DAVE HOLT INSPECTING CROP	VO For David Holt, developing an effective strategy for dealing with the nematodes began with a better understanding of their life cycle.
DAVE ON CAMERA	GRAB FROM DAVE 'In the last few years we've started to track nematode populations within our soil. We've seen a consistent pattern developed. At the end of a crop of sweetpotatoes we're seeing quite large numbers ..’ (23:59:13:00 - 23:59:35:00)
VARIOUS SHOTS RESIDUE LEFT IN PADDOCK & COVER CROP VARIOUS SHOTS RESIDUE LEFT IN PADDOCK & COVER CROP CONT.	VO In response, he now commits only 65 of his 100 hectares to growing sweetpotatoes each year. How he manages the remaining 35 hectares has become the key to reducing nematode populations in his farming system. GRAB FROM DAVE 'In the last few years we have changed our farming practices more to

	(23:47:19:00 - 23:47:24:00) paddock hygiene, in keeping your paddocks clean of anything that will host nematodes. Also we plant a lot of cover crops ... that do not host nematodes as well, and if we're planting sorghums they will be a high foracic acid sorghum.' (23:45:51:00 - 23:46:10:00)
DAVE ON CAMERA	GRAB FROM DAVE 'During the crop cycle of sorghum or whether it be triticale through the wintertime we do apply a selective herbicide to take out any hosts of nematodes.' (23:46:34:00 - 23:46:44:00)
SHOT OF REGROWTH IN COVER CROP	VO Reducing opportunities for nematodes to flourish between crops has paid off for David.
COVER CROP	GRAB FROM DAVE 'By having it fallow or having cover crops in the ground for that 12 month period we have found that after that 12 months the nematode counts are extremely low.' (23:57:01:00 - 23:57:11:00)
VARIOUS SHOTS PLANTING	VO With the ability to start new plantings with a low nematode count, David is now suffering less damage to his sweetpotato crop. And during the growing period he can manage the pest more effectively. But optimizing the cover cropping strategy has been an ongoing process. GRAB FROM DAVE 'We've found about 12 months best suits us in our cropping cycles between the end of a crop of sweetpotatoes and the commencement of another crop. There's a few reasons for this…'
DAVE ON CAMERA	GRAB FROM DAVE CONT. 'The first one would be that we believe we can get a cover crop in, get a lot of bulk back into the soil so our soil health hopefully is in good shape because of that but also with the amount of cost that

DAVE ON CAMERA CONT.	red soil costs now a days the return on investment dictates that you can’t afford to sit for too long.’ (23:55:30:00 - 23:56:02:00)
SHOTS OF COVER CROPS	VO The time and effort it takes to manage the cover crop has been another important consideration. GRAB FROM DAVE 'During the last two years we have trialled a few different varieties of sorghum. Some varieties of sorghum, the most recently released sorghum, we’ve found to be quite finicky and you really seem to have to farm it rather than just plant it in the ground and walk away from it…’
DAVE ON CAMERA	GRAB FROM DAVE CONT. ‘So we’ve started to move away from that and we’ve tried to get a variety of sorghum that is more tolerant to extended dry periods and hence we can just walk away and let it be.’ (23:49:56:00 - 23:50:28:00)
SHOTS OF DAVE PLANTING SORGHUM WITH MINIMUM-TILL PLANTER SHOTS OF DAVE PLANTING	VO With the benefits of using a cover crop well established, the next stage was to maximize its effectiveness in reducing nematode numbers. This began with improving the planting and coverage of the sorghum or triticale. GRAB FROM DAVE ‘One of the changes has been we have introduced a minimum-till planter. The benefits we believe in having a minimum-till planter is that we can get very good seed placement and also we can apply fertilizer at the same time. We found the range of conditions that it can operate in is greatly enhanced as well. We also calibrate the machine only twice a year, once for sorghum, once for triticale for the wintertime.’ (23:48:27:00 - 23:48:54:00) 'We used to use the old waggy-tail spreader and we had the problem of, you know, there's quite a bit of overlap at

SORGHUM WITH MINIMUM-TILL PLANTER CONT.	times. It was thin, it was thick and then if you were spreading up against an existing crop you had a bit of contamination going into there as well…’
DAVE ON CAMERA	GRAB FROM DAVE CONT. ‘So with the minimum-till planter we have found we've been able to place the seed to try and get the best result possible and also to get the density that we actually require.' (23:51:24:00 - 23:51:49:00)
SHOTS OF MULCHING & TILLING THE SORGHUM BACK INTO THE SOIL	VO Efficiencies were also found when returning the cover crop to the soil. GRAB FROM DAVE 'Once we believe the sorghum has reached a size that is of good density that we can get a lot of bulk back into the soil, we try to incorporate it as efficiently as possible and we're down to one pass now where we use a mulcher and rotary hoe in one pass. And we have found by doing this not only does it get the sorghum into the ground effectively and efficiently…’
DAVE ON CAMERA	GRAB FROM DAVE CONT. ‘…but we've also found the lead time between when we put a crop of sorghum into the ground and when we can plant is greatly reduced because we are able to break it down a lot quicker.’ (23:53:42:00 - 23:54:19:00)
SHOTS OF MULCHING & TILLING THE SORGHUM BACK INTO THE SOIL AERIAL FARM	VO The use of cover crops to help control nematode populations has become a major weapon in the sweetpotato grower's arsenal. Together with a better understanding of the nematode life cycle, growers can tailor an approach that will integrate with their whole-of-farm strategy. MUSIC VO CONT. It will help reduce chemical usage during the cropping period and contribute to improved yields and consistency of

	product. And as David Holt has found, the benefits are wide-ranging. GRAB FROM DAVE 'We've noticed since we've been putting a lot of mulch back into the soil through cover cropping…'
DAVE ON CAMERA	GRAB FROM DAVE CONT. '…that we're seeing not only our soil health improving and nematode counts going down but also an environmental benefits as well. We're seeing less sediment loss - our soils not getting washed out nowhere near severe in those large rain events – and we're able to hold the nutrient in the paddock. ' (00:14:21:00 - 00:14:46:00)
GRAPHIC: WHOLE OF CROP STRATEGIES WITHIN THE CROPPING PERIOD	MUSIC ENDS
VARIOUS SHOTS OF MATT PRICHARD INSPECTING CROP	VO Matthew Prichard is a grower at Cudgen in Northern New South Wales. He has 48 hectares of undulating country, of which 26 hectares are used each year to produce sweetpotatoes. Like David Holt in Bundaberg, Matthew has adopted a range of techniques to control nematode, wireworm and weevil populations on his farm. GRAB FROM MATT 'Over the last three years we've really focused on cultural controls to reduce numbers of sweetpotato pests before planting.' (6:35:53 - 6:36:01)
MATT ON CAMERA SUPER: MATTHEW PRICHARD GROWER/ASPG PROJECT COLLABORATOR	GRAB FROM MATT 'Some of the cultural controls that we have focused on include residue removal, removal of volunteers in cover crops, and great farm hygiene.'

CUDGEN	(6:36:10 - 6:36:22)
VARIOUS MATT INSPECTING CROP	VO Of the 3 major pests, root knot nematode represents Matthew's greatest risk. While the other pests can affect the crop at various times throughout the growing period, the nematode is active all the time. Even when cultural controls reduce nematode counts to very low levels prior to planting, the developing sweetpotato storage root provides a perfect opportunity for a damaging nematode invasion.
AERIAL MATT'S FARM	VO CONT. It is then that 'in-crop' management becomes a critical issue. GRAB FROM MATT 'I believe the best management practices for controlling root knot nematodes in sweetpotatoes include' (06:33:48:00-06:33:55:00) ...... 'pest population monitoring and crop protectants.' (6:35:18:00 - 6:35:21:00)
MATT ON CAMERA	GRAB FROM MATT 'Over the last 5 years we have learnt to identify our major sweetpotato pests and understand their life cycles which has allowed us to specifically time crop protection products for better outcomes.' (7:02:45 - 7:03:01)
VARIOUS SHOTS TRICKLE TAPE BEING LAID OUT	GRAB FROM MATT 'Prior to the adoption of these techniques the industry had a blanket chemical approach to sweetpotato pests' (7:06:19 - 7:06:27) ...... 'Growers were using it just in our normal irrigation T-Tape system and we found that we got inconsistent results because of poor attention to detail with product placement.' (06:39:28:00 - 06:39:40:00)
MATT ON CAMERA	GRAB FROM MATT 'The cost of chemical application for the

	control root knot nematode is a little over $1000 per ha, but the cost of applying these chemicals poorly is significant.' (6:30:05 - 6:30:17)
GRAPHIC: ANIMATION OF CHEMICAL IN ROOT ZONE	VO As growers better understood nematode behavior it became apparent that to provide adequate protection chemicals needed to be evenly distributed through the root zone, and stay within the root zone. This is especially true of the nematicide Vydate which is permitted for use in sweetpotato crops.
MATT ON CAMERA	GRAB FROM MATT 'Vydate is a highly soluble product and getting placement into the root zone is essential so we had to monitor our water movement through the soil to ensure that we placed the product in exactly the right place to protect our roots of the sweetpotato.' (6:40:08 - 6:40:25)
VARIOUS SHOTS LAYING TRICKLE TAPE.	VO Over the years Matthew had adopted practices commonly used by growers to minimize time and labour. Irrigation systems were being extended beyond recommended operational specifications. Irrigation lines had been run over longer distances and trickle irrigation systems were laid out across larger and larger blocks. And when applying chemicals through the system, the injection points were some way from the delivery sites. It became obvious that these factors were working against achieving precise placement of crop protectants in the sweetpotato root zone.
HIGH ANGLE AERIAL OF MATT'S FARM	VO Matt Prichard faced a further hurdle in achieving a more targeted approach to chemical delivery.

	GRAB FROM MATT ‘We found in Cudgen that we got uneven application of water and chemicals due to our undulating country so we had to ...... really focus on our treatment techniques to ensure even application of chemicals.’ (6:50:07 - 6:50:22)
MATT WITH GPS	VO One of the first changes he made was to reduce the size of each irrigated block. This meant trickle tape run-lengths were optimized to maintain a more even water pressure across the field - regardless of the slope. This in turn helped reduce variations in the amount of chemical delivered at one end of the block compared to the other.
MATT AT TRACTOR	VO Next, Matthew modified where chemicals are introduced into the system. Rather than using an injection point at the pump station where overall distribution across the farm was controlled, he moved closer to each treatment area. Using the tank on his spray rig as a mobile reservoir he is now better able to manage the injection and flush times for each field – an important consideration in preventing the chemical from being leached out of the root zone through excessive wetting of the soil profile.
MATT TESTING PRESURE IN TRICKLE TAPE.	VO With these changes in place Matthew now accurately manages the trickle tape system in each block, ensuing the correct amount of chemical is delivered exactly where and when it is needed. MUSIC
VARIOUS SHOTS PACKING SHED	GRAB FROM MATT ‘Our aim is always to look towards reducing chemical applications.’ (6:51:58 - 6:52:38) 'The outcome of using these improved techniques is’ ... (6:55:02 - 6:55:06) ... ... ‘now our chemicals are more targeted

	…... giving us more consistent results.' (07:09:30:00 - 07:09:37:00) 'In previous years we've had some significant crop losses due to root knot nematodes of somewhere between 10 and 20 percent per annum. We're now reducing that to around less than 5 percent.' (6:27:43 - 6:27:59)
AERIAL FARM SUPER GRAPHICS: THIS PUBLICATION HAS BEEN PRODUCED AS A RESULT OF PROJECT VG09052 INTEGRATION OF CROP AND SOIL INSECT MANAGEMENT IN SWEETPOTATO. LOGOS: ASPG INC, HORTICULTURE AUSTRALIA, AUSVEG	MUSIC TO END
	DUR: 17'41"

7. Farm visits

A structured part of the project process was for project staff to visit key growers in the major sweetpotato growing regions for one on one discussion of project results. During the course of the project in excess of 150 farms visits specifically related to the project were carried out in the following production areas: Rockhampton, Bundaberg and Cudgen. On two occasions the project accompanied major retail chain category managers on farm tours of production districts to discuss project matters.

8. Australian Sweetpotato Growers Inc.

One of the key components of the project was the project steering committee with grower representation from the key sweetpotato production areas of Rockhampton, Cudgen and Bundaberg. The steering committee met to review project results and plan further activities for VG09052. The steering committee, now known as the R&D committee, met at the following times;

1. November 2011, ASPG Inc Annual General Meeting, Cudgen
2. March Mid-Term project review 2012, Gatton Research Station
3. April 2012, ASPG Inc general meeting, Bundaberg
3. September 2012, ASPG Inc Annual General Meeting, Bundaberg
4. May 2013, ASPG Inc general meeting, Cudgen
5. November 2013, ASPG Inc Annual General Meeting, Bundaberg

9. HAL VG05037 Milestone Reports

1. Milestone 102 August 2010 Media requirements

2. Milestone 104 August 2011 Media requirements
3. Milestone 106 August 2012 Media requirements
4. Milestone 108 August 2013 Media requirements

Impact and adoption

From 2010 to 2013 project VG09052 engaged with 263 participants across 13 events. If attendance is a measure of impact and adoption then the technology transfer activities would be rated as extremely successful, with a significant number of growers and industry stakeholders attending events in each region. Clients from agri-businesses that service the sweetpotato industry were also in strong attendance at many of the meetings in the regions. At Bundaberg shed meetings it was common to have all local rural supply store agronomists present (Rural Advantage, BGA, Lindsay Rural, Norco and Elders Rural) and agri-chemical representatives present from DuPont, Syngenta, Nufarm, Crop Care, Bayer and Dow. Also attending VG09052 events were Central Queensland University staff, QLD DAFF officers and market agents from the major capital cities.

Chapter 5: Conclusions and recommendations

Whole of crop integrated management systems: Investigations between sweetpotato cropping periods:

Cover cropping: Identify key barriers and drivers for effective cover cropping systems in a sweetpotato whole of crop integrated pest management system. Growers are seeking ever-quicker cover cropping solutions to arrest pest populations in their sweetpotato farming systems. Economic barriers are perceived as the greatest driver for growers seeking fast acting cover cropping solutions. The pressure to return ground to income production is currently minimising the potential effective duration of cover cropping systems. Cover crops that can provide alternative and direct economic benefit could potentially improve duration and effectiveness of cover crops utilised in sweetpotato whole of crop integrated management systems.

Pest monitoring: High variability in root knot nematode soil count data is a limiting factor in the commercial uptake of this monitoring technique across the sweetpotato industry. A review of methodology of root knot nematode sampling in vegetable cropping systems is needed, as is the development of investigations that optimise the accuracy of the sampling strategy in sweetpotato farming systems.

Whole-of-crop integrated management systems: Investigations within the cropping systems:

Pest monitoring and chemical delivery: Sweetpotato weevil has not been causing major economic yield losses across the production districts throughout the majority of the project period (2010 to 2013). McCrystal (2010) reported that the over dependence on two crop protectant compounds to control sweetpotato weevil may lead to potential insecticide resistance developing. The 2013/2014 production season has seen sweetpotato growers incur major economic yield loss due to sweetpotato weevil infestations within the shortest crop development periods. Investigations need to be implemented that quantify the key factors that have lead to the current significant sweetpotato weevil pest incursions occurring across the sweetpotato production regions. This would provide a catalyst for further uptake of sweetpotato weevil monitoring technology; lead to better seasonal forecasting abilities; and the more accurate scheduling of crop protectants within the crop development period.

Chemical delivery: Seek a chemical minor use permit for the application of fipronil at various times throughout the sweetpotato crop development period. Further investigate soil drenches identified in pot experiments as providing systemic protection against adult sweetpotato weevil feeding injury on above ground plant parts. Ensure investigations into new nematicides are undertaken that include treatment regimes with various applications throughout the crop development period.

Germplasm: Continue to screen germplasm with traits that provide both desirable consumer characteristics and meet supply chain requirements and that provide improved tolerances to pests in sweetpotato cropping systems.

Chapter 6: Acknowledgements

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