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Improving the Sustainability of Plant Protection in Tea Tree Oil Production Systems

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by Peter Entwistle

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Foreword

The production of Australian tea tree oil is an emerging industry. It has been steadily growing since the 1980s and is now a contributor to the agricultural sectors in north-east New South Wales and the Atherton Tableland in Queensland. The industry has a plant protection system that is currently facing a number of challenges in terms of insect pest and weed control. The recent incursion of myrtle rust into Australia is also a potential threat to the industry.

Insect pests and weeds are having an increasing impact on tea tree oil production systems; leading to reduced profitability for growers through increased pest management costs. Declining prices for tea tree oil are combining with these rising costs, to further reduce profitability. More effective management options are required for growers to maintain profitability through sustaining high yields.

The project has developed a number of insect and weed management options that will help growers improve yields and profitability. Two insecticides have been identified that allow for more effective integrated pest management. Two post-harvest pre-emergent herbicides have also been identified that will improve early coppice weed control in plantations. A selective herbicide for the control of a problem weed species has also been identified.

Tea tree oil producers are already implementing some of the changes, as the permits for the safe use of the herbicides have been granted. Growers will then have an increased number of weed control options at their disposal.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Tea Tree Oil R&D program, which aims to enhance production systems to maintain the competitiveness of Australian growers.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

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Peter Entwistle of North East Agricultural Service is an agronomist and consultant working in the tea tree industry in north-east New South Wales. Peter has been providing an advisory service to the industry for the past ten years.

Acknowledgments

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Contents

Tables

Executive Summary

What the report is about

The Australian tea tree industry is an emerging industry that needs ongoing research and support for growth and profitability. While recent industry research has highlighted tree breeding and market development, this report looks at developing alternatives to some of the current practices that growers carry out on a day-to-day basis. Its focus is on insect pest management and weed control during the cropping cycle, and fungicides that could be used against the potential threat of myrtle rust.

Who is the report targeted at?

This report is targeted at all producers in the Australian tea tree industry. Growers are a diverse group, with plantation areas ranging from 5 to 700 hectares. Some growers are small and part-time; others employ numerous staff and have a significant investment in capital and machinery. All scales of producer will benefit from the outcomes of the report through improvements to their management systems.

Where are the relevant industries located in Australia?

The majority of tea tree is grown in the Richmond/Wilson, Clarence and Hastings River valleys in north-east New South Wales, with a smaller group of growers on the Atherton Tableland in northern Queensland. There are approximately 80 registered grower members in the Australian Tea Tree Industry Association (ATTIA). The majority of these, around 60, are in north-east New South Wales.

The total oil production from the industry is 450–500 tonnes per year. The majority of oil is exported to European and North American markets. There is also approximately 150,000 m^3 of by-product (spent leaf) sold as mulch in the landscape industry.

Background

Leaf-eating Pyrgo beetles (*Paropsisterna tigrina*) are the major insect pest of tea tree during the growing season. A limited range of ‘hard’ insecticides are the only options available for its control. Recent wet seasons have seen greater levels of spraying and the effectiveness of the program is diminishing. Resistance to insecticides beta-cyfluthrin and deltamethrin has developed and beneficial insect populations normally associated with the crop have diminished.

Weed control has also become harder in recent seasons. Grass management is still effective due to the crop’s broadleaf nature, but broadleaf weeds and sedges have become dominant in some plantations. Biennial and perennial weeds not killed post-harvest are persisting and the wet seasons have seen sedges and species such as *Cuphea carthagenensis* proliferating. Post-harvest pre-emergent herbicides are one option for reducing weed impact. The use of an over-the-top broadleaf herbicide is also desirable. The use of more effective directed sprays using shielded apparatus needs investigation.

Myrtle rust is a recent introduction into Australia and tea tree has been tested as susceptible. If the disease starts to have an economic impact on the crop, a number of fungicides have been made available by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Field testing and laboratory analysis is required to determine if any of these fungicides are suitable for tea tree.

Aims/objectives

The aim of this research was to enhance production systems and to maintain the competitiveness of Australian tea tree producers by:

- identifying more effective chemical control options for Pyrgo beetles, determining any risk of chemical residue in tea tree oil from these pest control options, and obtaining permits from APVMA for the selected insecticides
- identifying safe and effective selective broadleaf herbicides, post-harvest pre-emergent herbicides and in crop directed spray herbicides for use in tea tree, and obtaining permits from APVMA for the selected herbicides
- determining the suitability of emergency fungicides for myrtle rust control in tea tree.

Methods used

Insect control
'Soft' insecticide options were identified from an investigation into products used in other Australian industries. Controlled laboratory bioassays were carried out to determine which of the potential options were effective in controlling both adult and larvae forms of Pyrgo beetle. Field trials of viable options were carried out to determine their efficacy and the risk of residue in tea tree oil. Further large-plot field trials in a commercial situation were carried out to determine how the various options fit within the tea tree management system.

Weed control
Post-harvest pre-emergent herbicide options were trialled in commercial plantations in replicated small plots. Treatments were hand applied just prior to budburst after the knockdown control had been applied. Assessments of efficacy and crop phytotoxicity were made. Selected options were further field tested before a minor use permit application was submitted. Broadleaf selective herbicide options were applied over the crop during the early coppice period, and both efficacy and phytotoxicity were assessed. Directed spray options were hand applied to the side of the coppice, close to the season midpoint, and similar assessments of effectiveness were made.

Fungal control
Fungicides for myrtle rust were applied in the absence of rust to determine if any phytotoxic effects occurred. Leaf samples were taken and a lab distillation carried out to determine if any fungicide residue persisted in the oil.

Results/key findings

Insecticides for Pyrgo beetle control
The compounds indoxacarb and abamectin were found suitable for controlling Pyrgo beetles in a tea tree integrated pest management (IPM) system. Indoxacarb (150 g/L) is registered in Australia for use on cotton, soy and a range of other bean crops and the rate determined for tea tree was 300 mL/ha. Abamectin (18 g/L) is currently used on a wide range of fruit and vegetable crops along with ornamentals in Australia, and the rate determined for tea tree was 300 mL/ha.

Indoxacarb and abamectin are already in use in the tea tree industry and having a positive impact, partly through larger numbers of beneficial insects remaining in the crop. A residue study showed that harvesting of the crop can be carried out one month after application of both products. APVMA issued PER 12985 on 13 December 2011 for the use of abamectin and indoxacarb in tea tree plantations in New South Wales and Queensland.

Herbicides for weed control
The herbicide methabenzthiazuron was identified as having potential for use as a selective broadleaf herbicide in tea tree plantations. It was the safest over-the-top option and displayed encouraging weed control potential, but further trialling will be required to ascertain the safest use pattern for tea tree.

Simazine and metolachlor were identified as post-harvest pre-emergent herbicides that are safe for use in tea tree. Both are presently permitted for use in the plantation establishment stage of tea tree production. They can be used in combination to significantly reduce grass, broadleaf and sedge weed germination during the early crop coppicing stage. Simazine can be applied at 1.1–1.6 kg/ha (900 g/kg) or 2–4 L/ha (500 g/L) prior to budburst. Metolachlor (720 g/L) can be applied at 2–4L/ha. An accidental finding during the pre-emergent trials was the activity of the herbicide linuron (500 g/L) in controlling *Cuphea carthagenensis* when applied over the top of coppice growth at 1 L/ha.

When applied as a direct spray, glufosinate (200 g/L) and paraquat/diquat (135 g/L,115 g/L) were effective in controlling weed growth in tea tree coppice. Other trialled options gave effective weed control but had phytotoxic effects on crop growth. If directed to the lower part of the regrowth, glufosinate can be applied at 2 L/ha with minimal effect on growth. Paraquat/diquat at 2 L/ha can also be used safely as a directed spray to the lower part of the coppice.

Of the herbicides, permit applications have been submitted for simazine and metolachlor. APVMA is currently processing these and they are expected to be in place for the 2012/13 cropping season. A permit application has also been submitted for the use of linuron for over-the-top broadleaf weed control. Glufosinate is currently being investigated for registration for use in tea tree by New Rural Industries Australia (NRIA). Paraquat/diquat is already registered for weed control in tea tree.

Fungicides for myrtle rust control
The fungicides triademinol, propoconazole, azoxystrobin, mancozeb and tebuconazole were applied to tea tree. None of these caused any phytoxic effects on crop growth. Lab distillation and subsequent testing of oil samples did not detect any fungicide residues.

Implications for relevant stakeholders

Introduction of the insecticides indoxacarb and abamectin will have benefits for producers including:

- greatly improved control of Pyrgo beetle, and there are already signs that the number of insecticide sprays per season would be significantly reduced (thus lowering both insecticide cost and application costs, and reducing soil compaction)
- improved IPM through a greater reliance on beneficial insects for Pyrgo beetle control
- greater flexibility in choosing control options within three months of harvest
- reduced use of harder pesticides such as dimethoate and methomyl.

Introduction of post-harvest pre-emergent herbicides simazine and metalochlor will have benefits of:

- improved weed control during the early coppice period after harvesting
- reduced impact on crop growth from difficult-to-kill broadleaf weeds and sedges
- greater crop dominance over weeds at an earlier stage, leading to a reduced reliance on directed and selective sprays later in the crop.

Introduction of glufosinate as a directed spray herbicide will have benefits of:

- improved control of problem broadleaf weeds and sedges prior to crop closure
- reduced reliance on glyphosate as a shielded spray for later-stage weed control.

The community and the environment in general will benefit from the increased flexibility in plant protection in tea tree. Implementing the changes in pesticide use as outlined in the report will see improved insect pest and weed control in tea tree and lead to a reduced reliance on insecticides and herbicides overall.

Recommendations

Once all APVMA permits are in place, Australian tea tree growers have the option to implement the changes to their plant protection management as outlined in this report. The changes will bring improvements to their production systems and increase the ability of growers to remain profitable in the future.

Introduction

Effective insect pest management is one of the key areas for productive tea tree plantations in Australia. Pyrgo beetle (*Paropsisterna tigrina*) is in the chrysomelid group and is the main pest of tea tree plantations; yield loss can be as high as 80 per cent if not managed effectively. The monoculture structure of plantations and almost constant flush growth during the warmer months encourage the pest to flourish. Populations reach far higher levels than in natural bush situations where a beneficial/pest insect balance is normally maintained. Multiple generations of the pest normally occur within each season. Wet conditions also favour the development of pest populations. A delay in control by a few days when populations are peaking can lead to rapid defoliation and stunting of growth.

The 2009/10 tea tree growing season demonstrated the limited effectiveness of the registered or permitted insecticide suite in controlling Pyrgo beetles in plantations. This growing season saw very high populations of Pyrgo beetles attacking crops in all parts of the New South Wales Northern Rivers region. The frequency of pesticide application was increased and despite this, severe damage still occurred in a number of areas. Early spring populations were generally low but with the onset of wet weather in early January the population increased rapidly. Numerous sprays were used but options were limited to low residual ‘hard’ pesticides such as beta-cyfluthrin and methomyl. Dimethoate was not available for this period due to its long harvest withholding period. Wet weather delayed access on more than one occasion and severe crop damage was the result. Ongoing repeated control events were required and this became very expensive. Significant yield loss occurred in some plantations despite the high frequency of spraying. This strategy will become less affordable economically if prices for tea tree oil decline in the future.

Effective management of insect pest populations is critical to the future viability of the industry. The current chemical insecticide program relies on ‘hard’ pesticides that are only partially effective and expensive when used repeatedly. The main chemicals currently used are dimethoate, deltamethrin, beta-cyfluthrin and, methomyl; all of which are hard on beneficial insects that can be present in tea tree crops. The more common beneficials include ladybirds, tachinids, hover flies, predatory shield bugs, assassin bugs and spiders. High populations of beneficials can occur naturally and these can be effective in reducing Pyrgo beetle activity to lower than economic thresholds. Predatory shield bugs can be particularly effective in attacking all lifecycle stages of Pyrgo, including egg rafts. Collateral death of these beneficial insects when applying insecticides often leads to uncontrolled outbreaks of pests when subsequent wet weather limits access for further spraying. The result is severe defoliation and this can occur several times a season, leading to greatly reduced yields.

‘Softer’ alternatives that are more selective and have less impact on beneficial insects are required for more effective pest control in the Australian tea tree industry. A number of these products are widely used in other crops in Australia and it needs to be determined if any are suitable for tea tree oil production. The preservation of shield bug populations along with other beneficials would be an ideal outcome. A number of the ‘hard’ chemicals currently used are under review by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and future bans are possible; dimethoate is an example of one such chemical used in tea tree production. Alternatives to ‘hard’ insecticides need to be found before possible future bans occur and control options are further limited.

Broadleaf weeds and sedges are becoming increasingly difficult to manage in tea tree plantations. Levels of infestation vary from year to year but there are a number of species that are becoming increasingly difficult to manage, such as *Verbena* spp, *Gomphocarpus* spp, *Sida* spp, *Cuphea carthagenensis*, *Juncus* and *Cyperus* spp. The difficulty is usually related to the large size of most of the broadleaves or the regular germination of all species after rainfall events.

The location of weeds in the plant line of a crop also restricts control options due to the phytotoxic effects that most herbicide options have on the growing crop. Control in the inter-row can be achieved with shielded applications of glyphosate and 2,4D but weeds in the plant line are difficult to target safely.

The only permitted selective herbicide, clorpyralid, can only be used as a directed spray and this is ineffective in controlling a number of dominant weed species. There is an urgent need for other broadleaf/sedge selective herbicides to be available. There is also a need for the effective use of pre-emergent herbicides after harvesting. Growers are often caught out with broadleaf weeds when wet weather limits access and post-harvest knockdown herbicides are followed by rapid germination. There are a number of pre-emergent herbicides that could possibly be used at this stage in tea tree, as used in other industries. The use of post-harvest pre-emergent herbicides is aimed at extending effective weed control after harvesting. This is the period that offers the best opportunity to kill existing weeds and suppress future germination with minimal risk to the crop. Pre-emergent herbicides could be sprayed over the tea tree stumps and the surrounding soil to stop weed germination while the stump is shooting and developing coppice growth. The removal of all leaf growth after harvesting would be required to ensure this application is safe. Good weed control and strong coppice growth at this point will allow the crop to dominate. This should also reduce the need for further weed control later in the crop growth cycle. A range of pre-emergent herbicides are already being used during the establishment phase of tea tree plantations, including simazine, metolachlor, pendimethalin and linuron. A number of these may be suitable for post-harvest applications.

Broadleaf weeds are most difficult to control during the early growth in a tea tree plantation. A number of large-growing species such as *Verbena* spp. and *Gomphocarpus* spp. regularly dominate tea tree crops if they germinate soon after the stumps shoot. Broadleaf herbicides used in other industries may be effective on these species if applied over the top of regrowth. Trialling of a range of herbicides is required to determine weed control effectiveness and growth effects on the crop. Herbicides do not have to provide outright control of weeds but they do at least need to allow the crop to dominate any weed growth that is present.

Myrtle rust has the potential to devastate tea tree production in Australia. Myrtle rust was introduced to the country in early 2010. The first infection in commercial tea tree plantations was identified in early 2011. The level of infection increased in autumn and then again from late spring. Commercial damage is yet to occur but cannot be ruled out at this stage. The use of fungicides may be necessary if the rust starts to impact tea tree plantations at some stage in the future. The APVMA has recommended the use of a range of fungicides for the control of myrtle rust. This recommendation is mainly based on work carried out to control myrtle rust in other countries. The safety of use, including impacts on tree growth and oil residue potential, of APVMA-recommended fungicides needs to be determined to ensure they can be used if needed in the future.

Objectives

The objectives of the research are to enhance production systems and to maintain the competitiveness of Australian Tea Tree producers by:

- identifying more effective chemical control options for Pyrgo beetles in tea tree, determining any risk of chemical residue in tea tree oil from these control options and obtaining permits from the APVMA for the selected effective insecticides

- identifying safe and effective selective broadleaf herbicides, post-harvest pre-emergent herbicides, and in crop directed spray herbicide options for use in tea tree and obtaining permits from the APVMA for the selected effective herbicides

- determining the suitability of emergency fungicides for myrtle rust control in tea tree.

Methodology

Selection and testing of chemicals for Pyrgo control

The investigation of more effective chemical control options for tea tree included a consultative period in which growers, researchers, and chemical companies contributed. The integrated pest management systems of other industries were also investigated to see if control options could be used similarly in tea tree. The possible chemical control options were selected from this process. The chemicals were selected with potential Pyrgo control, minimal impact on beneficials, and low risk of residue in mind. The chemicals selected for testing were indoxacarb, fipronil, imidacloprid, and abamectin. A Bayer experimental product number 092 was also included as it was available at the time of testing. Beta-cyfluthrin and dimethoate were also tested as current industry standards.

The laboratory bioassay was carried out by Craig Maddox at the New South Wales Department of Primary Industries Entomology Unit, Alstonville. The method was developed previously. The bioassay work was conducted as in RIRDC project DAN-91A (Campbell and Maddox 1996[1]) under Gus Campbell using dip test assays of early instar Pyrgo larvae. The methodology used was as follows:

Two types of egg-laying arenas were used for the adult beetle colonies: a larger field cage (40 cm X 40 cm X 40 cm) with fresh leaf placed in conical flasks; and a 4 L opaque plastic Tupperware container with a ventilated lid. The latter was far more productive with the addition of soaked dental wicks to increases the humidity. Both arenas were maintained over the entire trial period feeding on regrowth flush leaf generated on the June harvested tea tree at Alstonville. Leaf changes were made on Mondays and Fridays to get a series of egg batches available for testing each week. The old leaf was examined at each change and fresh egg rafts stored in a petri-dish overnight, any newly emerged larvae were also used in the chemical screening.

Pesticide assays were conducted on Tuesdays if enough egg batches were available; if not, a re-examination of the new leaf normally allowed it to proceed on Wednesday each week. A series of three replicates were used for each dose of each chemical and normally 10 different series were attempted each assay. The leaf for each dipping was taken from a single high terpinene-4-ol variety of *Melaleuca alternifolia* plant, broken up into a pile of at least 30 twigs with a stem 8–10 cm long, a single terminal bud and at least 5 leaf pairs. The three twigs for each dose were immersed in the test solutions for at least 10 seconds, allowed to sit on filter paper to absorb the excess, then inserted into 10 mL vials of water through a 2 mm lid hole. This vial was placed on a white-filter-paper lined 10 cm diameter metal lid. The egg rafts (normally with 5–8 eggs but sometimes >12) and any 1st instar larvae were added to foliage using fine paint brushes and probes. Egg rafts with visible hatching spines were the best as they were going to hatch within 12 hours. The vial was then covered by a 300 mL Vacola glass jar and labelled by chemical/dose/replicate.

Each of the preferred chemicals were mixed on the day just prior to application at the determined top dose rate using calibrated pipettes, demineralised water and A grade volumetric flasks. The dose range was created using a serial dilution in 50 mL and 25 mL flasks, halving the concentration over eight steps. An untreated control and a beta-cyfluthrin reference (0.5 mL/L) were also used in each assay.

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[1] Campbell AJ and Maddox CDA 1997, *Controlling Insect Pests in Tea Tree Using Pyrgo Beetle as the Basis*, RIRDC publication no. R97/062, Rural Industries Research and Development Corporation, Canberra.

After each of the requested chemicals was screened in an individual assay series, a summary assay of each at the effective dose was repeated as a direct comparison and double check. Mortality screening was undertaken at 24, 48 and 72 hours and 7 days after the egg rafts and larvae were placed on the dipped leaves. The mixed ages of the eggs affected the speed at which the chemical was encountered by the insect, so mortality after 3–7 days was probably the best dose indicator. Larvae capable of any movement were deemed to be alive. This was determined using 7x magnification and a microprobe; anything doubtful was referred to the Zeiss stereomicroscope (10–64x magnification).

The level of leaf feeding was also estimated after 7 days to determine the point at which foliage was too toxic for the beetle to develop. As a measure it is probably even more important to know what level actually stops them feeding. This was done by examining the margins of the terminal bud and youngest leaf pair using 7x magnification to look for more than 20 per cent leaf removal.

To conclude the study, surviving adults were then tested against the standard knockdown chemical beta-cyfluthrin at the normal and double rate. Three replicates of five adults were placed on the twigs in vials and a single spray (fine mist setting) to each side was applied using a hand-held misting bottle (500 mL). Mortality was determined as before.

A small plot field trial was set up to test the chemicals that performed the best in the laboratory bioassay. The chemicals chosen for the field trial were imidacloprid, abamectin, indoxacarb and fipronil. The trial was set out in a commercial tea tree plantation at Casino, 'Blue Dog', owned by Glenn Donnelly during the 2010/11 cropping season. The growth stage of the crop was mid coppice at approximately 1 m high. The plots were 10 m by 2 rows (2 m) wide. Three replicates of each treatment were applied. A knapsack sprayer was used to apply the insecticides using flat fan nozzles at 2 bar pressure. The knapsack was calibrated to apply approximately 250 L/ha of solution, ensuring good coverage of the crop and even distribution of the chemical. Pyrgo populations were assessed a week prior to insecticide application and a composite leaf sample was also taken. The crop was assessed in terms of both pest incidence and leaf damage as a result of Pyrgo activity. A rating scale of 1–5 was used which combined pest levels and damage. A score of 1 represented high pest levels and the resulting severe crop damage; a score of 5 represented nil pest activity and no damage. Assessments were made at 3, 7, 14 and 21 days after application. There were eight treatments applied: indoxacarb (150 g/L) at 250 mL/ha and 500 mL/ha; imidacloprid (350 g/L) at 43 mL/ha and 86 mL/ha; abamectin (18 g/L) at 250 mL/ha and 500 mL/ha; and fipronil (200 g/L) at 25 mL/ha and 50 mL/ha. Rates were selected based on being below and above the recommended rates from the laboratory bioassay.

Further plot trials were carried out at the property of Robert Dyason at Leeville and again at 'Blue Dog' to confirm the results from the small plot trial. The larger plot trial at 'Blue Dog' was used to obtain residue data, with leaf sampling occurring at 14 day intervals after application.

Post-harvest pre-emergent herbicide application

The investigation into post-harvest applied pre-emergent herbicides included consultation within the industry, consultation with relevant research and agronomic staff within the New South Wales Department of Primary Industries, chemical company technical staff and, a study of previous research. The selection of chemicals was based on what was expected to give the best control of the suite of weeds in tea tree plantations and which ones would be likely to have the least impact on subsequent coppice growth.

The RIRDC project DAN74A provided an excellent background study of previous herbicide research in the industry. Numerous trials were carried out that provided the basis for the registration and permits for many of the herbicides currently used in the tea tree industry. Simazine, metolachlor, oryzalin, linuron and pendimethalin are all currently permitted for use as pre-plant applications during the planting phase of tea tree plantations. Only oryzalin is currently permitted for post-harvest application and effective rates are considered to be too expensive for economic use. Oxyflourfen was previously registered in tea tree but was apparently withdrawn due to phytotoxic effects on tea tree. Imazethapyr is currently used in the soybean and other pulse industries for broadleaf weed control.

The small plot field trial was set up at the property of Paul and Pat Bolster at Chinderah. Plots were marked out at 10 m long by 2 rows (2 m) wide. Treatments were replicated three times. Pre-emergent herbicides were applied after a post-harvest knockdown mix of glyphosate (450 g/L) at 2 L/ha and 2,4D (475 g/L) at 1 L/ha. This ensured that no weeds were present at the time of application of the pre-emergent herbicides. The treatments were applied with a knapsack sprayer with a 2 m boom using flat fan nozzles at 2 bar pressure. The solution was applied at approximately 250 L/ha to ensure good coverage of the soil surface. The solution was applied over the whole area of the tea tree stump line and the inter-row to simulate a commercial spraying operation. Assessments of weed control and crop phytotoxicity were made at 14, 28 and 42 days after application. A 1–5 rating scale of weed control was used, with 5 being complete control with no germination and 1 being full germination and unimpeded subsequent growth. A 1–5 scale for crop phytotoxicity was also applied, with 5 being no effects from the applied herbicide and 1 being significant impact and possible death of the tea tree stumps. The ratings were combined to give an overall score for the effects of the herbicide treatments. The treatments applied were: oxyflourfen (240 g/L) at 4 L/ha; metolachlor (720 g/L) at 3 L/ha; simazine (900 g/kg) at 1.5 kg/ha and 3 kg/ha; simazine + metolachlor at 1.5 kg/ha and 3 L/ha respectively; imazethapyr (700 g/kg) at 70 g/ha; linuron (450 g/L) at 2 L/ha; and pendimethalin (330 g/L) at 9 L/ha.

Further larger plot trials were carried out with the selected pre-emergent herbicide options at ‘Melaleuca Plantations’ at Bungawalbyn and ‘Blue Dog’ at Casino. These trials were used to confirm that there was minimal risk of phytotoxicity for the tea tree crop.

Selective broadleaf herbicide application

The investigation into broadleaf selective herbicides for use over the top of tea tree was again initiated with a consultative process with relevant researchers, chemical companies and industry. RIRDC project DAN-74A was again used as a starting point.

The difficulty of controlling broadleaf weeds in a broadleaf crop has been highlighted in previous work in this area. Clorpyralid has been permitted in the past for unrestricted over-the-top application; its use is now limited to a directed spray, due to reported residue issues experienced by one grower. This product is quite selective and has little impact on most of the problem broadleaves. This will be used as a comparison in the trial to assess the performance of other options.

The small plot field trial was set up at the property of Glenn Donnelly at Leeville near Casino. Plots were marked out at 10 m long by 2 rows (2 m) wide. Treatments were replicated three times. The treatments were applied with a knapsack sprayer with a 2 m boom using flat fan nozzles at 2 bar pressure. The solution was applied at approximately 250 L/ha to ensure good coverage of the weeds and the crop. The coppice regrowth was approximately 1 m tall at the time of application. The site was chosen as it had a good range of broadleaf weeds and sedges present. Assessments of weed control and crop phytotoxicity were made at 7, 14, and 21 and 42 days after application. A 1–5 rating scale of weed control was used, with 5 being complete weed death and 1 being no control or unimpeded subsequent growth. A 1–5 scale for crop phytotoxicity was also applied, with 5 being no effects from the applied herbicide and 1 being significant impact and possible death of the tea tree. The ratings were combined to give an overall score for the effects of the herbicide treatments. The herbicides applied were: oxyflourfen (240 g/L) at 4 L/ha; aciflourfen (224 g/L) at 1 L/ha and 2 L/ha; linuron (450 g/L) at 2 L/ha; bentazone (480 g/L) at 2 L/ha; bromoxynil (200 g/L) at 1.4 L/ha; methabenzthiazuron (700 g/kg) at 1 kg/ha and 2 kg/ha; and clorpyralid (300 g/L) at 750 mL/ha.

Directed spray herbicide application

The investigation into directed spray options followed a similar consultative process as for the other trials. Herbicides were chosen with the view to controlling sedges and broadleaves within plant line and outside the area targeted by shielded sprayers. The types of herbicides that would be considered are broadleaf selectives and desiccating type herbicides. Paraquat/diquat is currently used to desiccate small weeds and remove residual leaf after harvest and can be safely used to target small weeds with a directed spray to the base of the tree.

The trial was carried out at the property of Robert and Libby Dyason at Leeville south of Casino. The treatments were applied using a knapsack sprayer and a single nozzle at 2 bar pressure. The spray was directed to the side of the crop from the ground to 40 cm above the ground. Both sides of 2 rows by 10 m were treated and this was replicated three times for each treatment. This application was designed to simulate the directed spray equipment currently used in the tea tree industry. The approximate application rate was 180 L/ha. The crop was approximately 1 m tall at the time of application. The application was intended to give thorough coverage of weeds and the lower part of the crop. The herbicides applied were: oxyflourfen (240 g/L) at 4 L/ha; aciflourfen (224 g/L) at 2 L/ha; fluroxypyr (200 g/L) at 300 mL/ha; linuron (450 g/L) at 2 L/ha; glufosinate-ammonium (200 g/L) at 2 L/ha; 2,4D (475 g/L) at 1 L/ha; imazethapyr (700 g/kg) at 100 g/ha; paraquat (250 g/L) at 1.2 L/ha; and paraquat/diquat (135 g/L,115 g/L) at 2 L/ha.

Myrtle rust fungicide investigation

The fungicides investigated for myrtle rust control were selected from the permits released by the APVMA for a range of industries. Tebuconazole and tebuconazole/trifloxystrobin were selected as possible future control options. Myrtle rust was not present the time of application of the fungicides as it had not spread to the Northern Rivers region at this stage.

The treatments were applied to small plots on the property of Paul and Pat Bolster at Chinderah on the 19/10/10. The plots were 10 m long by 2 rows (2 m) wide. A small boom was used to apply the solutions at 2 bar pressure with a water rate of approximately 250 L/ha. The fungicides applied were: triadimenol (250 g/L) at 200 mL/ha; propoconazole (500 g/L) at 250 mL/ha; azoxystrobin (250 g/L) at 160 mL/ha; mancozeb (420 g/L) at 3.5 L/ha; tebuconazole (200 g/L)/trifloxstrobin (100 g/L) at 150 mL/ha; and tebuconazole (430 g/L) at 290 mL/ha.

Assessments of phytotoxicity were made at 7, 14 and 21 days after application. Leaf samples for residue analysis were taken 35 days after application.

Results

Selection and testing of chemicals for Pyrgo control

Bioassay

The results of laboratory bioassays were provided by Craig Maddox.

The chemicals trialled and minimum and maximum doses were listed in Table 1. The active rates were determined by working from the lowest dose where the mortality was 100 per cent across all three replicates at day 3 and also looking at the rates where no leaf feeding on the terminal flush could be seen at day 7. These active doses are recorded in Table 2.

Table 1: Chemicals used and the dose range trialled against *Paropsisterna tigrina* eggs and 1st instar larvae during July–September 2010 at CTH Alstonville

Active chemical (conc)	Trade name	Population tested	Dose range tested
Indoxacarb (150 g/L)	Steward 150	Eggs + Lv	0.015–2.0 mL/L
Imidacloprid (350 g/L)	Confidor Guard 350	Eggs + Lv	0.0038–0.5 mL/L
Abamectin (18 g/L)	Stealth 18	Lv	0.008–1.0 mL/L
Fipronil (200 g/L)	Regent 200sc	Eggs + Lv	0.004–0.5 mL/L
Beta-cyfluthrin (25 g/L)	Bulldock 25EC	Eggs + Lv + Adults	0.5–2.0 mL/L
Dimethoate (400 g/L)	Dimethoate 400	Eggs + Lv	3.4 mL/L

Table 2: Bioassay results for the chemicals used against *Paropsisterna tigrina* eggs and 1st instar larvae during July–September 2010 at CTH Alstonville. The average number of eggs and larvae tested per replicate and the lowest doses that gave 100% mortality and no significant leaf feeding presented as mL product/L water mixture.

Active chemical	Eggs tested (ave. per replicate)	Day 3 100% Mortality (mL/L)	Leaf feeding limit (dose mL/L)
Indoxacarb	7	1.0	0.5
Imidacloprid	6	0.0038	0.0075
Abamectin	8	0.5	0.5
Fipronil	8	0.125	0.031
Beta-cyfluthrin	8	14/78 survived (18%)	Not 0.5 mL/L

An initial run with an older formulation of indoxacarb 200 WG was trialled and appeared totally ineffective at 4 g/L so new product was sourced by Peter Entwistle. Fipronil was the first run scored followed by imidacloprid, abermectin then indoxacarb. Another two compounds were also trialled in the final comparative assay at regularly used rates for other crops. These were emamectin and the new Bayer 092 formulation (see Table 3) which has appeared very effective in our macadamia work at CTH Alstonville. The relative price (as of 12 October 2010) of the product applications was then calculated at the effective doses to give the growers some guide as to the overall cost per litre of water applied of the various mixtures.

Table 3: **Follow up comparative bioassay for *Paropsisterna tigrina* survival and leaf consumption at the non feeding doses at CTH Alstonville.** Price of each compound to get the effect at the applied dose rate per litre water used.

Active chemical **(rate mL/L)**	**Trade name (vol)**	**Leaf feeding**	**Cost**per litre mixed at applied dose**
Indoxacarb (0.5 mL/L)	Steward (10 L)	No	$0.042
Imidacloprid (0.01 mL/L)	Confidor Guard (10 L)	Yes	$0.0024 raise to 0.03 mL/L
Abamectin (0.5 mL/L)	Stealth (5 L)	No	$0.014
Fipronil (0.03 mL/L)	Regent (5 L)*	No	$0.012
Bayer 092 (1 mL/L)	Exp. formulation	No	Unknown
Emamectin (0.1 g/L)	Proclaim50 g/K 600 g	No	$0.041
Current products			
Methomyl (2.0 mL/L)	Lannate (20 L)	Not done	$0.027
Beta-cyfluthrin (0.5–1 mL/L)	Bulldock 25EC (20 L)	Yes–Yes	$0.012–0.024
Dimethoate (3.4 mL/L)	Dimethoate 400 (20 L)	No	$0.044

** Cost based on prices currently listed (12 October 2010) at NRRBS and Norco Rural stores Lismore and Alstonville NSW. Divide price in dollars for volume of product listed by number of doses in volume purchased (drum volume/effective dose).
* Generic versions of this product should be available now which could make it even cheaper.

Table 4: Survival rates of *Paropsisterna tigrina* and leaf consumption observed for the untreated control and reference beta-cyfluthrin treatments in each assay done at CTH Alstonville

Active chemical (rate mL/L)	Life stage tested	Assay run	3 days mortality #live/total pop.	Leaf feeding After 7 days
Untreated control	Eggs + Lv	1	8/13	yes
Beta-cyfluthrin (0.5 mL/L)	Eggs + Lv	1	0/16	yes
Untreated control	Eggs + Lv	2	3/12	yes
Beta-cyfluthrin (0.5 mL/L)	Eggs + Lv	2	0/19	no
Untreated control	Eggs + Lv	3	16/27	yes
Beta-cyfluthrin (0.5 mL/L)	Eggs + Lv	3	9/15	yes
Untreated control	Eggs + Lv	4	20/21	yes
Beta-cyfluthrin (0.5 mL/L)	Eggs + Lv	4	3/16	yes
Untreated control	Eggs + Lv	5	10/23	yes
Beta-cyfluthrin (0.5 mL/L)	Eggs + Lv	5	1/26	yes
Beta-cyfluthrin (1.0 mL/L)	Eggs + Lv	5	3/27	yes
Dimethoate (3.4 mL/L)	Eggs + Lv	5	3/25	no
Untreated control	Adults	6	15/15	yes
Beta-cyfluthrin (1.0 mL/L)	Adults	6	2/15	yes
Beta-cyfluthrin (2.0 mL/L)	Adults	6	0/15	no

The final assay (assay run 6, Table 4) was conducted on the surviving adult beetles that had provided the eggs for all the assay work. The results were disturbing given that the adults were not all dead when treated at the rate of 1.0 mL/L and an examination of the other assays shows some level of larval survival occurring at the field rate of 0.5 mL/L (see Table 4). The variability in the control mortality also suggests that the imidacloprid bioassay (run 2) would give a lower value than the other assays and this is supported by the repeat run finding a higher dose needed to stop feeding than originally predicted (Tables 3 and 4).

Given the possibility of resistance to beta-cyfluthrin developing on the data presented here it is strongly advised that the growers look to broaden the chemical groups used to control the pest. It does appear that the beetles are still controlled by dimethoate and lannate (anecdotal evidence) some of these newer options are not dearer than the current applications and appear effective under these laboratory conditions. The real test is the field trial directly against a dimethoate treated block and the following doses would be a good trial for the likely replacements (see Table 5).

Table 5: Suggested field dose rates for the control of *Paropsisterna tigrina* based on the laboratory trials done at CTH Alstonville July–September 2010

Active chemical (conc)	Trade name	Suggested field dose mL/L given that 50–100 L/ha are applied for dimethoate then (L/ha)
Indoxacarb (150 g/L)	Steward 150	0.5 mL/L or (25–50 L/ha)
Imidacloprid (350 g/L)*	Confidor Guard 350	0.03–0.05 mL/L or (1.5–5 L/ha)*
Abamectin (18 g/L)	Stealth 18	0.5 mL/L or (25–50 L/ha)
Fipronil (200 g/L)	Regent 200sc	0.03–0.05 mL/L or (1.5–5 L/ha)
Standards		
Methomyl (225 g/L)	Lannate	2.0 mL/L or (100–200 L/ha)
Beta-cyfluthrin (25 g/L)	Bulldock 25EC	0.5–2.0 mL/L low rates or (25–200 L/ha)
Dimethoate (400 g/L)	Dimethoate 400	3.4 mL/L or (170–340 L/ha)

*Field rates are only estimates as the initial assay (run 2) has high control mortality (75%) suggesting the larva in this assay were not as robust as those in the other trials. When repeated in the follow up assay leaf feeding was still detected at the rate of 0.01 mL/L, time constraints prevented more trials of this chemical but it is an option that field trials will resolve.

Field trials

The initial field trial was carried out at Casino. Scoring indicates a moderate level of damage was present in all plots and high numbers of Pyrgo were present (Table 6).

Table 6: Insecticide ratings at 21 days after application

Treat	Insecticide/active chemical (conc)	Rate per ha	Score
1	Indoxocarb (150 g/L)	250 mL/ha	4.33
2	Indoxocarb (150 g/L)	500 mL/ha	4.33
3	Imidacloprid (350 g/L)	43 mL/ha	3.66
4	Imidacloprid (350 g/L)	86 mL/ha	3.33
5	Abamectin (18 g/L)	250 mL/ha	4.33
6	Abamectin (18 g/L)	500 mL/ha	4
7	Fipronil (200 g/L)	25 mL/ha	3.66
8	Fipronil (200 g/L)	50 mL/ha	4

The trial was heavily affected by a number of high rainfall events. This actually limited control options in the adjacent commercial part of the plantation. Insect pressure increased quickly in the untreated buffer areas around the trial and provided a good test of the capability of the insecticides.

Leaf samples for residue assessment were taken at 5 and 13 weeks after application. Reports WN/10/2309/E and WN11/0190/E, provided by the Industry and Investment Environmental Laboratory at Wollongbar, found that all samples were below the Limit of Reporting (<1.0 mg/L) for indoxocarb and fipronil or below the Limit of Quantitation (=0.01 mg/L) for abamectin and imidacloprid.

Indoxacarb and abamectin were selected as the insecticide options to subject to further field testing. Both these insecticides performed well in the plot trial and with good control of Pyrgo adults and larvae after application. Control was still effective 21 days after application. While very few beneficial insects were present during the trial, both of these insecticides have known benefits for preserving beneficial populations in integrated pest management (IPM) in other crops.

Imidacloprid was disappointing in the trial with some larvae survival at both rates soon after application. Pest populations had started to build up again 21 days after application. Fipronil was effective in the trial but was slightly less so than abamectin and indoxocarb. Fipronil is also expensive and was likely to be persistent in the oil after distillation.

Indoxocarb and abamectin were both selected at rates of 300 mL/ha for application in tea tree. These rates are above the lower rate used in the trial and similar to rates used in other industries. The findings of the bioassay also support these rates.

Larger plot trials were set up on two plantations near Casino. One replicate of each treatment was applied on both sites with plots approximately 1 hectare in area. These applications were very successful in controlling Pyrgo and ongoing monitoring proved these to be the last applications for the 2010/11 growing season. Reduced impacts on beneficial insects were noted.

A small plot residue study was carried out at ‘Blue Dog’ near Casino. The analysis of leaf samples was carried out at 10 and 20 days after application of both abamectin and indoxocarb at 300 mL/ha. Reports WN11/0990/E and WN11/0945/E, provided by the Industry and Investment Environmental Laboratory at Wollongbar, found that neither insecticide was above the Limit of Reporting or Limit of Quantitation for leaf and oil.

Post-harvest pre-emergent herbicide application

The post-harvest pre-emergent trial was carried out at Chinderah near Tweed Heads starting on 29 November 2010. The treatments were applied under good conditions but heavy rain continued for a number of months after the start of the trial. The trial was inundated a number of times during the trial period and this had some adverse effects. A number of weed seedlings were drowned by regular inundation and this distorted some of the control results. The length of control of all treatments was less than would be normally expected. The site did contain some problem weeds including *Cuphea carthagenensis* and a number of *Cyperus* spp. The recent wet seasons have seen these species become more significant as they are suited to these conditions. Good control of these species after harvest is an excellent outcome. Table 7 shows the results of the small plot trial.

Table 7: Post-harvest pre-emergent herbicide ratings 35 days after application

Treat	Herbicide/active chemical (conc)	Rate per ha	Score
1	Untreated control		5.00
2	Oxyflourfen (240 g/L)	4 L/ha	6.00
3	Metolachlor (720 g/L)	3 L/ha	5.33
4	Simazine (900 g/kg)	1.5 kg/ha	6.33
5	Simazine (900 g/kg)	3 kg/ha	6.67
6	Simazine (900 g/kg) + metolachlor (720 g/L)	1.5 kg/ha + 3 L/ha	6.67
7	Imazethapyr (700 g/kg)	70 g/ha	5.67
8	Linuron (450 g/L)	2 L/ha	5.00
9	Pendimethalin (330 g/L, 9 L/ha)	9 L/ha	5.00
10	Untreated control		5.00

The results in Table 7 indicate that simazine was the most effective herbicide when applied on its own. The problem species *Cuphea carthagenensis* was only effectively controlled by simazine. Metolachlor showed the best ongoing control activity on sedges in subsequent evaluations as the effectiveness of other treatments started to decline.

One accidental finding of this trial was the apparent effectiveness of linuron when applied to healthy growing *C. carthagenensis* in coppice tea tree. This was discovered when spraying out the last residue onto an adjacent early coppice area just to see what would happen to the coppice growth. The resulting good control of the weed with only a minor impact on the crop led to further investigation in other stages of the project.

Simazine and metolachlor were chosen as suitable post-harvest applied pre-emergent options to take to larger plot trials. This finding was supported by earlier work carried out in RIRDC Project DAN74A. This mix of pre-emergents is currently permitted for pre-plant use when establishing tea tree plantations.

Larger plot trials were applied at 'Melaleuca Plantations' and 'Blue Dog' at the start of the 2011/12 growing season. These trials proved the effectiveness of these options and no adverse effects were noted. The rate range for simazine is 1.1–1.6 kg/ha of 900 g/kg active while the range of metolachlor is 2–4 L/ha of 720 g/L active. The lower rate of each range is for lighter soils.

Selective broadleaf herbicide application

The selective broadleaf herbicide application was delayed until the 2011/12 growing season due to wet weather and the difficulty in sourcing one of the herbicides. The trial was carried out at Leeville in a commercial plantation owned by Glenn Donnelly. Weeds present included *Verbena* spp., *Sida rhombifolia*, *Solanum nigrum, Bidens pilosa* and *Cyperus* spp. Conditions for the application of the treatments were excellent with good soil moisture present and weeds actively growing. Weed species were larger than is desirable for selective weed control.

Table 8: Selective broadleaf herbicide ratings 20 days after application

Treat.	Herbicide/active chemical (conc)	Rate per ha	Score
1	Control		6.00
2	Oxyflourfen (240 g/L)	4 L/ha	5.00
3	Aciflourfen (224 g/L)	1 L/ha	5.67
4	Aciflourfen (224 g/L)	2 L/ha	6.00
5	Linuron (450 g/L)	2 L/ha	7.00
6	Bentazone (480 g/L)	2 L/ha	6.33
7	Bromoxynil (200 g/L)	1.4 L/ha	5.33
8	Methabenzthiazuron (700 g/kg)	1 kg/ha	7.67
9	Methabenzthiazuron (700 g/kg)	2 kg/ha	7.33
10	Clorpyralid (300 g/L)	750 mL/ha	5.67

The results in Table 8 indicate that methabenzthiazuron has significant potential as an over-the-top herbicide for broadleaf weed control in tea tree. This chemical has previously been permitted for use in tea tree; PER 4474 was allowed to expire in 2006. Further trialling will be required over the next growing season to determine if a permit should be applied for again.

The effectiveness of linuron is also significant. There was no *Cuphea carthagenensis* present on the trial site but the effectiveness of suppression of other weeds was encouraging. Phytotoxicity was minimal with only slight short term discolouration noted, at 20 days after application there was no sign of this. Test plots recently applied on other plantations have shown good potential for this herbicide. Linuron is already used safely for application over tea tree seedlings.

While products such as oxyflourfen and aciflourfen provided good weed control, the phytotoxic effects were too great for the chemicals to be considered in the future. Bentazone and bromoxynil were not very effective and will also not be considered in future trials.

Directed spray herbicide application

The directed spray herbicide trial was applied on 9 December 2011 at the property of Robert and Libby Dyason at Leeville. The conditions for application were slightly windy but the directed spray against the lower half of the crop was not affected. Assessment soon after application indicated that very little off target drift occurred. The site was a good one as a wide range of major broadleaf weed species were present including *Verbena* spp., *Gomphocarpus* spp., *Solanum nigrum, Sida rhombifolia* and, *Cyperus* spp. The growth stage of the weeds was advanced but the situation was not dissimilar to common commercial situations at this stage of the season. The scoring system used to assess the trial reflected the combination of weed control and crop phytotoxicity.

Table 9: Directed spray herbicide ratings 30 days after application

Treat.	Herbicide/active chemical (conc)	Rate per ha	Score		
			Weed	Phyto	Total
1	Control		1.00	5.00	6.00
2	Oxyflourfen (240 g/L)	4 L/ha	2.33	4.33	6.67
3	Aciflourfen (224 g/L)	2 L/ha	2.33	5.00	7.33
4	Fluroxypyr (200 g/L)	300 mL/ha	3.00	3.00	6.00
5	Linuron (450 g/L)	2 L/ha	2.00	5.00	7.00
6	Glufosinate (200 g/L)	2 L/ha	4.00	3.00	7.00
7	2,4D (475 g/L)	1 L/ha	3.00	3.67	6.67
8	Imazethapyr (700 g/kg)	100 g/ha	2.00	4.33	6.33
9	Paraquat (250 g/L)	1.2 L/ha	3.33	4.67	8.00
10	Paraquat (130 g/L), diquat (115 g/L)	2 L/ha	4.00	4.33	8.33

The results in Table 9 indicate that glufonsinate and paraquat/diquat proved to be the most effective for weed control. This included the complete death of *Verbena* spp. and *Gomphocarpus* spp. in most cases where the whole weed was covered. *Gomphocarpus* spp. in particular have proven very difficult to control in most cases in the past. The burning/dessicant behaviour of these herbicides and the sappy nature of the weed appear to have a good synergy for control. The phytotoxic effects of glufosinate decreased quickly after this point in the trial and could hardly be noticed one month later. The option of paraquat/diquat appears to be very safe despite severe defoliation of the lower part of the crop. The use of this option is very attractive where smaller weeds are present.

Other herbicides used in the trial, apart from paraquat on its own, were either ineffective on weeds or had significant phytotoxic effects. Imazethapyr caused longer-term stunting of the crop; one month later the crop was approximately 30cm shorter than other treatments.

Myrtle rust fungicide investigation

The myrtle rust fungicide trial was applied on 19 October 2010 at the Bolter's property at Chinderah. Samples were taken at 6 weeks after application and presented to the New South Wales Industry and Investment Environmental Analysis Laboratory at Wollongbar. It was found that no fungicide residues were detectable at this point.

Implications

APVMA PER12985 was issued on 13 December 2011 for the use of the insecticides abamectin and indoxacarb to control Pyrgo beetle in tea tree plantations. This has allowed growers to start using these insecticides in the 2011/12 growing season. Abamectin has been widely used already and has proven to be very effective in controlling Pyrgo and leaving a lot of beneficial insects in the crop, such as ladybirds and predatory shield bugs. The number of spray applications has fallen considerably, as much as 50 per cent, where abamectin has been used as compared to the previous two seasons. Evidence suggests that the remaining predatory insects are slowing the build-up of pests after spray application. The extreme wet period through the autumn of 2012 has seen much lower levels of Pyrgo beetles than in previous seasons. The use of indoxocarb has been restricted to those plantations that do not graze livestock in the tea tree plantation areas. The effect has been similar to abamectin with good levels of beneficials remaining after application and a buffering effect against pest build up.

A permit application has been submitted to the APVMA for the use of simazine and metalochlor as a post-harvest applied pre-emergent herbicide mix. This will provide growers with another tool against difficult to control broadleaf and sedge weeds in the early coppice stage of plantations. This application is expected to be approved for the start of the 2012/13 cropping season and is likely to have significant benefits for early coppice management in plantations.

A permit application has also been submitted to the APVMA for the use of linuron to control *Cuphea carthagenensis* in tea tree plantations. This weed has become a significant problem in many plantations in the Northern Rivers region of New South Wales and until now there have been no effective control options once post-harvest knockdowns have been applied. This option, combined with the use of post-harvest pre-emergent herbicides, is expected to see *C. carthagenensis* having far less impact on tea tree production in the future.

The project has not managed to successfully find any other broadleaf and sedge weed selective herbicides. Methabenzthiazuron has some potential but further work is required before a permit can be applied for with confidence. This area of management is still a limitation for the industry but will be buffered to some degree by advances in the use of post-harvest pre-emergents and the use of directed sprays to combat these weeds.

The use of paraquat/diquat as a directed spray is already occurring in the industry and this is likely to become more widespread as this report confirms the safety of its use. The spray can be safely used when applied to the bottom 30 per cent of the foliage as a directed spray. The use of glufosinate in tea tree is currently being applied for by New Rural Industries Australia (NRIA). Glufosinate is likely to be even more effective at killing small-size problem broadleaves as a directed spray.

The use of fungicides for the control of myrtle rust has not been required to date in commercial tea tree plantations. Recent issues with residue in lemon myrtle suggest that more detailed testing may be required if a commercial outbreak of the rust occurs.

Recommendations

The Australian Tea Tree Industry Association (ATTIA) will continue to disseminate the findings of the report as permits from the APVMA are released. This has already been the case with the insecticide permits that are currently in use.

Further research into the use of the herbicide methabenzthiazuron is required in tea tree plantations. This is likely to be funded by growers through the activities of North East Agricultural Services in the coming 2012/13 growing season. The area of selective broadleaf herbicides is still a weakness in managing commercial tea tree plantations.

The impact of myrtle rust on tea tree plantations has been very minor to date. Further investigation into residue risk is required if the fungus does start to have an impact.

Improving the Sustainability of Plant Protection in Tea Tree Oil Production Systems

By Peter Entwistle

Pub. No. 12/086

The Australian tea tree industry is an emerging industry that needs ongoing research and support for growth and profitability. While recent industry research has highlighted tree breeding and market development, this report looks at developing alternatives to some of the current practices that growers carry out on a day-to-day basis. Its focus is on insect pest management and weed control during the cropping cycle, and fungicides that could be used against the potential threat of myrtle rust.

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Cover image: Pyrgo beetle *Paropsisterna tigrina* courtesy Peter Entwistle