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**RHOPAEA CANEGRUB - ASSESSMENT
OF PEST STATUS AND AN RD&E
PROGRAM FOR IMPROVED
MANAGEMENT IN THE TWEED VALLEY**

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SUMMARY

I visited the Tweed Valley area to assess the pest status of *rhopaea canegrub*, diagnose reasons for grower dissatisfaction with present control options, and, with affected growers and technical staff, to develop a research, development and extension program aimed at improving management strategies for minimising the impact of these canegrubs.

My main findings were:

- ☞ *Rhopaea canegrub* is an economic pest of sugarcane in the Tweed area, mainly on the peat soils, and causes important losses to some of the otherwise most productive growers.
- ☞ The 1-year life cycle, poor dispersal by adult females, presence of larvae high in the soil profile, and the acidic, organic and friable soils all influence control options and the efficacy of these options.
- ☞ suSCon® Blue is giving inadequate control. The insecticide is being placed too deep to contact grubs and the low grub populations in the first 2 years following replanting means that the effect of much of the active ingredient is wasted.
- ☞ Knockdown insecticides have a limited potential because of the grub's 1-year life cycle and because crops are not irrigated.
- ☞ Cultural controls, such as rolling, plough-out and fallowing, and use of tolerant varieties have considerable potential for use as management tools.
- ☞ Green-cane trash-blanketing or trash incorporation may change the farming system in the medium-term future and their effects on *rhopaea canegrubs* are unknown.
- ☞ There is a core group of growers who are very aware of the problem and who are very enthusiastic about testing alternative and integrated management options.

A RD&E plan, which incorporates all of the above options, was developed in conjunction with growers and extension officers. This program should be developed for funding from SRDC and insecticide companies and would provide a good project for a postgraduate student. The key components of this program are:

- Better placement and later application of suSCon® Blue;
- Determination of the effects of ploughing and fallowing;
- Determination of the effects of trash retention and incorporation;
- Potential for the use of Mocap® and Rugby® as knockdown insecticides;
- Determination of the effects of rolling;
- Determination of the tolerance of Tweed-grown cultivars;
- Determination of chlorpyrifos susceptibility of *rhopaea canegrub*;
- Determination of the susceptibility of *rhopaea canegrub* to strains of *Metarhizium*;
- Integration of the useful options into a viable management strategy.

INTRODUCTION

Rhopaea canegrub (*Rhopaea magnicornis* Blackburn; brown beetle) is the major insect pest affecting sugarcane production in the Tweed Valley of northern New South Wales. The species is also common in pastures and lawns in southeastern Queensland and northeastern New South Wales. It occurs from near Nambour to Broadwater and west to the ranges. Difficulty in achieving acceptable control of the larvae is considered the major limiting factor on the production of sugarcane in the 'peat' soils of the Tweed Valley.

Management options to minimise the impact of canegrubs on the Australian sugar industry are moving from a strict reliance on synthetic insecticides to a system integrating a range of insecticidal, cultural and biological controls. Improvement in the control of *rhopaea* canegrub should logically follow the same path.

PURPOSE OF THE ASSESSMENT

I visited the Tweed Valley at the invitation of the Condong Crop Protection and Productivity Board during April 1996 to:

- Assess the pest status of *rhopaea* canegrub and the present control options.
- Diagnose reasons for grower dissatisfaction with present control options.
- Develop with affected growers and technical staff a research, development and extension program aimed at improving management strategies for minimising the impact of *rhopaea* canegrub.
- Recommend how this RD&E program can be progressed.

I inspected infested fields and talked with affected growers, and talked with technical staff (Hayes and McGuire). I also attended a meeting with about 20 interested (mostly affected) growers. We discussed present control attempts, possible control strategies and the development, implementation and collaboration in a research, development and extension project.

PEST STATUS OF RHOPAEA CANEGRUB

A. Hayes conducted a questionnaire survey of 150 Condong growers in July 1995. Of the 23 growers that replied, 10 did not have a problem with canegrubs. However, those affected include some of the better, highly productive growers, who probably have eliminated most of the other production constraints and need better grub management to make further productivity gains. Damage characteristically shows up in the third year following replanting (usually the second ratoon). In severe cases, damage demands

premature replanting, cutting short the cropping cycle.

Most damage is confined to the 'peat' soils. These are acidic, high organic-matter content loams to clay loams overlying marine clays. When drained they are highly productive canegrowing soils. In the past, damage has also been important on the basaltic loams of the Cudgen area, but these are now not growing sugarcane. Some damage has also been recorded in the Chinderah area on marine sands to sandy loams. Alluvial clay-loam soils do have low larval populations, but have no associated economic damage.

The basic biology of *rhopaea canegrub* has been determined by A. Hayes and is outlined in the Appendix. Important features that affect control are:

- **Generally a 1-year life cycle.** Adults fly in late October through mid December and lay eggs soon after mating. These hatch within 3 weeks. Larvae moult to second instars in January and to third instars in April. Pupation occurs in mid to late August.

This means that damage appears in well-grown crops in early autumn. Therefore, sampling is difficult and the use of knockdown insecticides will be restricted to late-harvested crops.

In years when the Autumn is cool, the species appears to require 2 years to complete development. This life cycle appears to predominate at Broadwater, where conditions are cooler.

This results in damage late in a crop or soon after harvest, similar to other 2-year canegrubs.

- **Females are poor dispersers.** Adults do not feed and females do not fly. Females mate on the soil surface or nearby posts, tree trunks or grass. They then return to the soil to lay eggs close to where they emerged.

This means that damage appears as a patch in a field, which over time gradually gets bigger. It also suggests that an infestation derives more from the carry-over population from the previous crop cycle than from invasion from other infested fields. Therefore, populations will be higher and damage more apparent in older ratoons than in the plant crop or first ratoon.

- **Larvae live near the soil surface.** Most larvae are found within 50-150 mm of the soil surface; this is much higher in the soil profile than most other canegrubs.

This means that contact insecticides such as suSCon® Blue must be placed high in the soil profile to be effective. It also means that rolling and surface application of knockdown insecticides could be effective.

- Favoured soils are acidic, high in organic matter and very friable. Most favoured soils are the peaty loams to clay loams.

The acidity of the soils is not likely to result in rapid degradation of chlorpyrifos and other organophosphates.

The high organic matter content could restrict the movement of surface- or coulters-applied insecticides through the soil profile.

The soil texture means that it is relatively easy to apply insecticides behind coulters or to adequately cover surface-applied insecticides.

PRESENT CONTROLS

suSCon® Blue

suSCon® Blue is currently registered at 28 kg/ha for 2-year control of rhopaea canegrub, although there may be some control exerted over the third-year population. The chemical is applied at planting or into the half-open furrow roughly following the label specification of being placed 150-200 mm below the final soil surface in a band 150-200 mm wide.

My observations are that this placement means that the suSCon® Blue band is usually well below the area where rhopaea grubs are feeding. Given that grubs have to contact at least one granule to acquire a lethal dose, the chemical will not work effectively. Application to the late fill-in stage should place the granules closer to the grub zone. The main restrictions on this method are that the granules must be covered immediately with 50 mm of soil to preserve the active ingredient content and that the band width must be 150-200 mm. These may restrict how late in the fill-in the insecticide can be applied.

Some growers also had gross misconceptions about the way that suSCon® Blue works, especially the movement of released chlorpyrifos. The release characteristics of suSCon® Blue and low mobility of chlorpyrifos in the soil were explained at the growers' meeting.

The other unknown is how susceptible rhopaea canegrub is to chlorpyrifos. This has been determined relative to other insecticides but not relative to other canegrubs. Such comparative information would give indications of useful insecticide rates and granule sizes. It should be measured using the assay system developed by Chandler under SRDC project BS49S to allow comparisons with other species and provide baseline susceptibility data for the detection of resistance.

One concern is that application into the plant crop coupled with the absence of damaging populations until the second ratoon means that the suSCon® Blue is effectively wasted in the first year or two. Application into the first ratoon would give an extra effective year of life to the insecticide.

Knockdown insecticides

Mocap® and Rugby® are currently registered for control of some southern Queensland canegrubs; neither is registered for use against *rhopaea canegrub*. However, Mocap®, at least, is effective in bioassays (Hayes, unpublished data) and has been used to a limited extent by a few growers.

Two factors will restrict the use of these insecticides. Both are more active if irrigation or significant rain closely follows application; none of the Tweed area is irrigated and rainfall may be erratic. The second is the grub's 1-year life cycle that means that the insecticide should be applied in February-March; this is only achievable in late-harvested crops.

However, the insecticides are potential management tools and their effectiveness and place in a management system should be determined.

Plough out and Fallowing

Plough out of infested crops and replanting with or without a fallow period is used by all growers as a last resort. This should reduce grub numbers and delay the onset of damaging populations in the following crop cycle. It is generally seen as unacceptable because of the loss in crop production, but this needs to be quantified. Ploughing during the fallow or leaving a bare fallow is unacceptable from the soil conservation viewpoint. A legume cover crop for the fallow may negate these problems and, if legumes are poor food sources, still keep the grub population at low levels.

Rolling

Many growers will roll the stools following harvest to set the stools firmly back into the soil. Growers report some grub control following rolling, and this seems logical given the location of the grubs and their fragile nature. Soil compaction may also have negative effects and the efficacy and unwanted effects need to be assessed.

Varietal resistance

Growers report differences in tolerance between cultivars grown. Hayes' survey showed that some growers consider that CP44-101, Q124, Co740, Pindar, Florida and Delta are more susceptible, while some thought that Co740, CP44-101 and H56-752 are more resistant. Obviously, the contradictory rankings of CP44-101 and Co740 require assessment. As a first stage, all Tweed-grown cultivars that can be sourced through the BSES Meringa collection should be screened as part of SRDC project BS132S.

Do nothing

Some growers elect not to treat fields so as not to interfere with natural predation and parasitism. Hayes reports that there are growers in potential damage-prone areas who have

never attempted chemical control and claim that they have not suffered damage. It is difficult to separate this approach from other cultural controls such as ploughing out, fallowing, rolling and use of more tolerant cultivars. However, the approach has never been quantified or researched.

Green-cane trash-blanketing (GCTB) or trash incorporation

Nearly all Tweed crops are harvested after burning. Some growers may then incorporate the remaining trash into the soil. The effects of GCTB or trash incorporation on *rhopaea* canegrub numbers are unknown, but, given likely moves away from burning, need to be determined.

Summary

- ▶ suSCon® Blue is not always being used efficiently - depth of placement and no need for control in at least the plant crops contribute heavily to this;
- ▶ Knockdown insecticides have a limited potential because of the absence of irrigation and the narrow window for application;
- ▶ Cultural controls such as ploughing, fallowing and rolling are used, but are generally unresearched and their value has not been quantified;
- ▶ Cultivar resistance has not been quantified, but growers suggest that there are differences and they are conscious of its potential role in pest management;
- ▶ Green-cane harvesting may be forced on growers and it is important that the effects of trash-blanketing or trash-incorporation on canegrubs is quantified.

PROPOSED RD&E PLAN OF WORK

The following plan was developed by affected growers, NSW technical staff and myself during and following the growers' meeting. It attempts to bring together many control elements into an integrated management strategy.

Work plan

1. **suSCon® Blue placement.** An extension campaign to encourage better placement of suSCon® Blue should be mounted.
2. **suSCon® Blue application into ratoon crops.** The efficacy of application of suSCon® Blue into recently harvested first ratoons following stubble shaving should be tested. Insecticide to be applied at 0, 14, 21 and 28 kg product per hectare to the soil surface and covered with at least 5 cm of compacted soil brought in from the interrow. Larvae to be counted in the first, second and third ratoon and yields taken at each harvest. Trial to be a randomised complete-block design with 5-6 replications and plots 5 rows wide and 10-14 m long. Trials should be established on 2-3 farms and material sought from Crop Care.

3. **Ploughing and fallowing.** The following combinations of ploughing and fallowing should be tested:
 - plough out previous crop, no fallow (replant);
 - plough out previous crop, fallow for 12 months with a legume cover;
 - minimum till removal of previous crop, no fallow (replant);
 - minimum till removal of previous crop, fallow for 12 months with a legume cover.

Plots will need to be large (one-quarter of a field) to show long-term effects. Populations to be monitored in each crop and yields taken. The four treatments should ideally be replicated at several sites.
4. **Green-cane harvesting.** The effects of green-cane trash-blanket, green-cane trash-incorporation and burnt-cane systems on *rhopaea canegrub* should be tested. Trial design and monitoring similar to 2 above.
5. **Knockdown insecticides.** Application of Mocap® (25 kg/ha) and Rugby® (about 22 kg/ha) to late-harvested infested ratoons should be tested. Insecticides to be applied by twin coulters or applied to the soil surface and raked in. Ideally to be followed by rain within 24 hr of application. Larvae to be counted in the following crop (April) and yields taken at harvest. It may be useful to monitor numbers in succeeding crops to determine carry-over effects of population reduction. Trial to be a randomised complete-block design with 5-6 replications and plots 5 rows wide and 10-14 m long. Material should be sought from Rhone-Poulenc (Mocap®) and Crop Care (Rugby®).
6. **Rolling.** The effects of rolling infested, recently harvested, first or second ratoon crops on grub numbers should be determined in trials similar to those used to test ploughing and fallowing.
7. **Cultivar tolerance.** The relative tolerance and any antibiosis effects should be determined for potential Tweed cultivars within the current project BS132S using the pot-based system and Bundaberg grub species. This could be done at Bundaberg, starting in September 1996 and delivering results by June 1997. The range of cultivars included would depend on which ones could be sourced from the BSES collection at Meringa or Bundaberg. Further local work to check the findings in the field could then be carried out.
8. **Chlorpyrifos susceptibility.** This could be determined for *rhopaea canegrub* using the standard system previously developed. This will require 200-300 young third instars and would be best carried out by Mr Chandler at Meringa. The work would take 7 days and would cost the NSW industry \$3 500.
9. ***Metarhizium* susceptibility.** Initial work should screen *rhopaea canegrubs* against strains of *Metarhizium* currently being field tested in project BS134S. Who would

do this screening needs to be determined, but initial approaches should be made to Dr Richard Milner, CSIRO Entomology, Canberra.

10. **Development of an IPM strategy.** All viable management options need to be integrated into a viable IPM strategy. This will require input from growers, extension officers and researchers.
11. **Extension.** Much of the above work must be on growers' farms and must rely on a strong grower input. The enthusiasm shown at the growers' meeting must be maintained. Hayes and McGuire will have an important role in coordinating this research, making sure that the results are communicated and adopted, and ensuring that grower enthusiasm and cooperation continues; they must 'champion' the project.

Outcomes

The program outlined above should result in several control options that can be integrated into a useful strategy. Combinations of treatments (tolerant variety, following a plough out and fallowing, rolling after harvest, with or without the use of suSCon® Blue into the first ratoon or knockdown or microbial insecticides into later ratoons) would appear to be viable in the long term.

Project development

The RD&E package outlined above could be developed as a project for SRDC funding and could include some further studies of grub biology. It lends itself to a student project (Development of an IPM package for rhopaea canegrub) and would have the support of the Department of Entomology, University of Queensland, if funding could be found. Other sources of funding could come from Crop Care and Rhone-Poulenc, at least in provision of insecticides for testing. The project would complement the current BSES canegrub R&D program and would involve extension input from McGuire and Hayes and participation from Condong growers through the Condong Crop Protection and Productivity Board.

SRDC funding could be sought for the 1997-98 financial year; this would require a preliminary project application during September 1996 and a full application in January 1997.

Indicative costs for the first year would be:

Salary - Student	\$22,000
Salary - UQ or NSW Agriculture entomologist (supervisor)	\$ 6,500
BSES Entomological consultancy	\$ 3,000
Travel - accommodation and fares	\$ 2,000
Operating - consumables	\$ 2,000
Operating - vehicle running costs	\$ 3,000
Capital - computer etc	\$ 4,000
Total	\$42,500

Costs in succeeding years (3.5 years in total) would be similar, without the capital cost. A vehicle and general support should be supplied by the NSW Sugar Milling Cooperative and insecticide should be obtained from Crop Care and Rhone-Poulenc. Todate, Crop Care has expressed a strong interest in participating.

APPENDIX

THE BROWN BEETLE, *RHOPAEA MAGNICORNIS* BLACKBURN IN SUGARCANE AT CONDONG, NSW

A G Hayes, Condong, March 1996

INTRODUCTION

Rhopaea magnicornis was recorded specifically as a pest in sugarcane in New South Wales in the early thirties, and as a pest of peanuts in southern Queensland (Chadwick 1970). It appears to be widespread throughout pastures in both areas along with other *Rhopaea* spp.

Sugarcane production intensified in the Tweed Valley in the late fifties through to the present. Virtually all the previously swamp soils (locally called 'peats'), have been effectively drained and are now highly productive canegrowing soils. They are acidic (pH 3.5 to 4.5) high organic content loams to clay-loams, overlying marine clays. When drained, these soils are a favoured habitat for the Brown Beetle. Significant damage was recognised through the sixties and again, in the early eighties. It was usually associated with prolonged dry weather. In the eighties, damage was also severe on the basaltic loams at Cudgen where cane production was declining for other reasons. These are well drained frost free and flood free sloping soils. It was interesting to note that damage there was worst on fields that had been growing alternative crops for some years, eg tomatoes and sweet potatoes. Both were subject to intensive insecticide use. The 'traditional' canefields ie those continually in cane production, were less affected. Some infestation and damage had been recorded in the Chinderah area on marine sands to sandy loams. The alluvial clay loam soils do have low larval populations but no associated economic damage.

THE INSECT *RHOPAEA MAGNICORNIS* BLACKBURN

The Brown Beetle has been comprehensively described by Chadwick (1970). Identification of the insect at Condong was initially based on morphological features, particularly aedeagus and antennae, and was confirmed by Dr P G Allsopp. Larval identification is difficult as there is some variation in the raster pattern and features are somewhat indistinct.

Chadwick based his assumption of a two year life cycle on the presence of third instar larvae at virtually all times of the year. However, damage patterns in sugarcane, specifically, excessive autumn lodging and, in dry years, untimely drought effects, suggested typical one year grub damage. Investigation showed this to be the more usual case. A trial with second instar siblings showed that those exposed to higher autumn temperatures moulted, overwintered as third stage larvae, pupated and emerged in spring as adults. The control group overwintered as second instar and moulted in spring, spending the next twelve months as third instars before completing their life cycle twelve months later. Attempts to define the 'trigger' temperature failed in subsequent trials.

FIELD INVESTIGATIONS

Uniformity

It has been suggested that different species, or races may be present and account for the severe damage in some areas. Limited larval measurements were undertaken from March until August to compare specimens from Cudgen (red basaltic loam), Chinderah (sandy loam) and Condong (alluvial clay loam). Cudgen larvae were slightly, but not significantly bigger, nor were there any other overt morphological differences. When bred through to adults, males were equally attracted to females from all districts. Damage patterns were probably a function of larval populations and environmental conditions. Cudgen showed most damage, had the highest populations and was the most drought prone area.

Life cycle

Adults emerge in late October through mid-December. Females climb up posts, tree trunks or grass. Males fly around until they locate females. Newly emerged females in cages were surrounded by males in minutes. As soon as one male couples with the female, the others disperse. They fly around looking for other females(?) and finally fly to lights. Males fly around particular trees, eg *Eucalyptus salignus*, *Macadamia tetraphylla*, and may temporarily alight on the leaves, but otherwise do not appear to have any specific relationship with them. Females have not been observed flying, nor have they been caught in light traps. Male beetles are approximately 23 mm long, 9 mm wide at the prothorax and 12 mm wide at the elytra. Females are a similar size. Flights to lights start at 1845 (EST) and usually continue for 15 to 20 minutes. They get later as the season progresses. Flights are only observed on warm, humid, relatively still nights - eg after summer storms.

The female returns to the ground and starts laying eggs several days after mating (uncertain of precise times). The eggs are relatively large, white, patterned and ovoid. They are approximately 4.5 mm long and 3.5 to 4 mm in circumference at the widest part. As many as 22 have been recorded from one female, although the number of observations is very limited. They start hatching from 5 to 22 days after the commencement of laying. Some of the eggs examined were parasitised by fungi and nematodes were observed in close association - (parasitic??).

The first instar larvae are approximately 10 mm long at hatching with head capsule width from 2-3 mm. Body segments are initially 1-1.5 mm wide. The larvae are white with the head capsule changing from creamy to red brown in the first one to two days. They live for approximately 6 weeks, moulting in January to form second instar larvae.

Second instar larvae are active in the soil from late January until April, ie approximately 10 weeks. They apparently feed on roots at this stage. Length ranges from 23-37 mm and head capsule width is between 4 and 5.5 mm.

The first of the newly hatched third instar larvae are found in early April. They are from 35-50 mm long with head capsule widths ranging from 7-8.5 mm. They feed voraciously on roots, and even sett remains. The preference is for grasses, but they have also been recorded as a pest of sweet potato. In the laboratory they have been fed on oats and clover roots, potato, sweet potato and carrot. Some second instar larvae are usually found with thirds throughout the winter months. In dry conditions, crop damage will be observed from April through June. Cane lodges severely and plants are easily lifted from the soil. Stools will be pulled out during harvest, both contaminating the cane delivery and creating gaps in the subsequent ratoon crop, or even preventing satisfactory ratooning in the following year. There is a range of varietal sensitivity to this type of damage. NCo310 was fairly tolerant, Pindar was susceptible. Of present day varieties, none are very tolerant and some, eg Q137 and Delta, are extremely sensitive. Damage by second year, third instar larvae is manifested by poor, slow establishing and gappy ratoons. This is similar to two year Frenchi and Consobrina damage in north Queensland, but not usually as severe.

Larvae enter the pre-pupal stage in mid to late August, enclosed in earth cells. As with all previous stages, they are within the rooting zone, usually within 15-20 cm of the surface. Pupation takes from 7-10 weeks. Limited counts at this stage indicate a male to female sex ratio of 2.4:1. Emergence as adults starts in the last week of October.

OTHER OBSERVATIONS

Climatic conditions and effects

Populations and attendant damage are greatest in sustained dry periods. However, wet weather does not appear to directly affect larvae. They do not drown in water, but enter a type of diapause and become totally inactive. Third instar larvae have been kept in tap water for up to 6 weeks without apparent harm, and have been transported *en masse* that way to other centres. Hence, flooding is unlikely to directly affect larvae, except during moults. However, wet conditions would have indirect effects by facilitating dispersion of parasites and pathogens, and by disrupting normal development eg moults and pupation.

Temperature and humidity affect adult emergence (see above).

Larvae mobility and feeding

Although larvae have been sustained on a variety of diets, they show a definite preference for grass roots. In the mid-1980s a green manure crop was planted on sandy loam soil at Chinderah. The seed was contaminated with grain sorghum, and the field had sorghum plants irregularly scattered across it at 5-20 m intervals. Every sorghum plant had larval infestation (1 or 2), in the roots. Larvae were not located anywhere else in the field.

In a trial at Cudgen where CR chlorpyrifos was used as a treatment, the outer guard rows showed significant damage and the next rows in showed greater damage than the inner

rows. This indicated that the outer rows had been damaged by migrating and feeding larvae. Bioassay trials had confirmed that larvae were not inhibited by chlorpyrifos as compared to BHC. It appears then that larvae are able to travel at least 3 m in the friable soils and this may partially explain why these soils are subject to greater damage and confirm the grower observation that grubs spread more rapidly in them compared to the alluvial soils.

Control

Chemical control was originally based on a South Queensland recommendation of 300 lb per acre of 20% BHC dust broadcast on the surface and incorporated. This was socially unacceptable and highly hazardous to operators. It was initially replaced with row treatment at one-third of the rate, but this still did not overcome the aversion that growers had to using this type of unpleasant material. A search for a better way was undertaken.

Various chemicals were bioassayed for effectiveness in pot trials. Chlorpyrifos and ethoprophos (Mocap®) were the best and diazinon was almost as good. The development of chlorpyrifos in a slow release granule met our safety criteria and this formulation was field tested under commercial conditions. In those trials where damage was inflicted in control plots the chlorpyrifos product gave financial benefits ranging from \$60 to \$260 per hectare. These trials were carried out on ratoon crops and placement was not always ideal. The recommendation finally adopted was for a rate of 28 kg per hectare of the new product, suSCon® Blue applied to the plant crop. This gives 3-year protection, although in actual fact it is only the second ratoon (third year) that will incur damage. Pre-plant cultivation and disturbance of the soil will destroy most larvae in the soil and they do not build up to damaging numbers until the third year. At the current cost of suSCon® Blue, it is a high insurance premium to pay for a crop 2 years hence, bearing in mind that seasonal conditions may mitigate against damage in that year.

An alternative approach is knockdown treatment with Mocap®. Because of better solubility, placement is not as critical and Mocap® can be effectively applied to ratoon crops. It is still expensive and only protects only one crop. However, the decision to treat can be left until the pest status is determined. The main objection is that Mocap® is a potent nematicide and there is a risk of interfering with a significant parasite by using it.

Alternatives to chemical control are, stool rolling, ploughout and fallow, or do nothing. Stool rolling means that growers run on the rows with tractors to apply pressure. This sets the stools firmly back in the ground after harvest. The insect is very fragile and being concentrated in the top soils is very prone to mechanical damage. The effect of resulting compaction on crop growth has not been assessed. This area warrants objective research.

Ploughout and fallow is a reactive treatment that in some years will involve yield loss in the third year of cropping followed by loss of normal production in the fallow year, and an additional cost of unscheduled planting. It is an unacceptable approach.

The 'do nothing' option has some validity. The basis of this approach is that natural control by parasitism and predation are not interfered with. There are growers in potential damage areas who have never attempted chemical control and claim they have not suffered damage. It is significant that those growers claiming losses today are generally highly producers who have followed past chemical recommendations and probably have significant residues in their soils. This is another area that needs investigation.

FUTURE PROSPECTS

Genetic engineering

The incorporation of genes for resistance, or tolerance is ideal if practicable. There is some evidence, or observation, that some varieties exhibit more tolerance to grub attack than others. However, I believe that this is controlled by agronomic characteristics rather than any inherent antagonism to the insect. It is likely that totally foreign genetic material will need to be incorporated to achieve real protection against attack.

Biological control

Fungal attack by *Metarhizium* sp. is common. There are probably other soil-borne agents such as bacteria, nematodes or viruses that may have future application. However, the practicality of preparing a bench stable product and applying it to the soil in sufficient concentration and adequate distribution and life expectancy is dubious at present. This area needs considerable research into, firstly, identification of candidate organisms and the logistics of preparation, storage and application. The ideal organism will need to be fairly specific, whilst still having activity against a range of other beetle larvae known to be plant damaging, so as to justify development costs.

REFERENCES

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