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Integration of klerat rodenticide into the IPM program for rodent control in sugarcane SRDC Project BS78S : final report

Story, PG

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FINAL REPORT
SRDC PROJECT BS78S
INTEGRATION OF KLERAT RODENTICIDE INTO THE IPM PROGRAM FOR RODENT CONTROL IN SUGARCANE
by
P G Story
SD95009

Principal investigator: Mr P G Story
Research Officer
Ingham SES
PO Box 41
INGHAM Q  4850
Phone: 077 762500

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1.0 SUMMARY

The second-generation anticoagulant rodenticide Klerat™ (0.005% w/w brodifacoum) was evaluated for inclusion in the integrated pest management (IPM) program for rodent control in Queensland sugarcane. IPM for *Rattus sordidus* in sugarcane relies on habitat manipulation techniques such as in-crop weed control and revegetation of noncrop refuges and requires the application of an efficacious rodenticide if high population densities are predicted. The commencement of the rodent breeding cycle was identified as the optimum rodenticide application time. The combined effect of time of baiting and in-crop weed control was evaluated. While bait application and weed control can reduce *R. sordidus* populations, successful crop damage reduction will only be achieved by widespread adoption of IPM strategies that minimise rodent invasion of crops as well as reducing breeding.

2.0 INTRODUCTION

Losses caused by rodents are common events in tropical agricultural systems. Of all the crops subject to rodent attack in the tropics, sugarcane and rice have received the most attention for management (Taylor 1972), but annual losses remain significant.

Rodent outbreaks have been documented in Queensland sugarcane since 1864 (McDougall 1944a; Plomley 1972), and such outbreaks have continued despite the implementation of control strategies. Since their inception in the 1920s, Cane Pest and Disease Control Boards (now Cane Protection and Productivity Boards) have recorded the presence of rat damage and the need for cane rat control (Egan pers comm). In addition, Weil’s disease or leptospirosis transmitted through rodent excreta was a major concern of canefield workers.

<table>
<thead>
<tr>
<th>Year</th>
<th>Raw sugar losses</th>
<th>Cost of treatment ($ 000)</th>
<th>Total cost ($ 000)</th>
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<tr>
<td></td>
<td>Tonnes</td>
<td>Value ($ 000)</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>10850</td>
<td>1950</td>
<td>297</td>
</tr>
<tr>
<td>1987</td>
<td>6460</td>
<td>950</td>
<td>167</td>
</tr>
<tr>
<td>1988</td>
<td>4470</td>
<td>975</td>
<td>260</td>
</tr>
<tr>
<td>1989</td>
<td>5350</td>
<td>1237</td>
<td>134</td>
</tr>
<tr>
<td>1990</td>
<td>6730</td>
<td>1485</td>
<td>86</td>
</tr>
<tr>
<td>1991</td>
<td>5714</td>
<td>1400</td>
<td>51</td>
</tr>
<tr>
<td>1992</td>
<td>19525</td>
<td>3880</td>
<td>185</td>
</tr>
<tr>
<td>1993</td>
<td>27500</td>
<td>5690</td>
<td>305</td>
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Source: BSES Annual Reports 1987-1993
Sugarcane yield loss through rat damage has always been regarded as significant although the extent of these losses has not always been quantified accurately. Crop losses due to rodents are now considered greater than early reports suggested; improved survey techniques and loss calculations indicate that monetary losses to the northern Queensland sugar industry can be severe (Table 1).

2.1 The species: *Rattus sordidus*, the canefield rat

The murid rodents (rats and mice) are amongst the least specialised and hence the most opportunistic and adaptable of rodents. Therefore, they are the group of rodents most favoured by the development of agricultural monocultures (Hampson 1982; Sanchez 1976). Polyoestrus breeding cycles, post-partum oestrus, short gestation periods and large litters give these rodents the ability to respond rapidly to a favourable change in environmental conditions (Whisson and Delaney 1989). Older and more fecund females dominate the social hierarchy and increase the chance of survival at times of low population densities. The result is the development of rodents as worldwide domestic and commercial pests (Kendall 1984). *Rattus sordidus*, the canefield rat, has one of the highest reproductive potentials of any native *Rattus* sp.

McDougall (1944b) listed the species and outlined general habits of the rodents then documented as responsible for damage to sugarcane. He documented five species occurring in sugarcane; these are listed in Table 2 with their current valid names. The canefield rat, *R. sordidus* and the climbing rat or grassland melomys, *Melomys burtoni*, are now commonly accepted as the most important species of native rodent damaging northern Queensland sugarcane. *M. cervinipes* has been caught in canefields and can cause crop damage, while *R. rattus* and *R. tunneyi* are not considered pests in Australian sugarcane (Hitchcock 1973; Redhead 1973; Watts and Aslin 1981).

<table>
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<tr>
<th>McDougall's (1944b) name</th>
<th>Current valid name</th>
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<tr>
<td><em>Rattus cornatus</em> Thomas</td>
<td><em>R. sordidus</em> (Gould)</td>
</tr>
<tr>
<td><em>R. rattus</em> Linnaeus</td>
<td><em>R. rattus</em> Linnaeus</td>
</tr>
<tr>
<td><em>R. culmorum</em> Troughton</td>
<td><em>R. tunneyi</em> (Thomas)</td>
</tr>
<tr>
<td><em>Melomys cervinipes</em> Troughton and Le Souef</td>
<td><em>M. cervinipes</em> (Gould)</td>
</tr>
<tr>
<td><em>M. littoralis</em> Troughton and Le Souef</td>
<td><em>M. burtoni</em> (Ramsay)</td>
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*R. sordidus* causes over 90% of the damage attributed to rodents in areas south of and including the Herbert River canegrowing region (Wilson and Whisson 1993). *M. burtoni* is responsible for significant sugar losses in the more heavily dissected, narrow valleys of the
far northern canegrowing regions where *R. sordidus* is also prevalent (Story 1993). Damage by *M. burtoni* is sometimes thought to be more significant to the sugar industry than that caused by *R. sordidus*. Damage caused by the grassland melomys is more visible and dramatic to the casual observer (Allsopp et al 1993) because it is usually confined to the edges of paddocks.

Approximately 75% of land assigned to cane growing is in areas where *R. sordidus* is responsible for over 90% of the total crop damage (Wilson and Whisson 1993). Hence, the canefield rat is more important to the industry than is *M. burtoni*.

*R. sordidus* damages cane at ground level by gnawing the cane rind. This exposes the cane plant to bacterial and fungal infection and results in sugar and weight loss. *R. sordidus* is a grassland animal that favours areas with a close ground cover of grasses, weeds and sedges. Habitats such as grasslands, grassed fringes of riparian vegetation, open forests, swamps and watercourses provide ideal conditions for this rodent. Because *R. sordidus* is a burrowing animal, undisturbed friable soil allows for extensive burrow networks to be established (McDougall 1944a,b; Taylor and Horner 1973; Lavery and Grimes 1974). *R. sordidus* makes tunnels 5-10 cm in diameter, often sloping downwards to a nesting chamber about 15 cm in diameter containing a bed of dry grass. It is a colonial species and networks of runways are formed between burrows which are normally no more than 40 cm deep. In canefields these burrows often follow cane rows, while in uncultivated areas burrow openings are found near grass clumps, stumps, fence posts, and large stones (Watts and Aslin 1981).

Sugarcane monocultures closely resemble the preferred native habitat of this species, providing good cover in the mature crop, protection from avian predators, friable soil and a readily available food source (Watts and Aslin 1981). Therefore, cane farms increase the carrying capacity of land inhabited by *R. sordidus* and encourage higher populations. In its native habitat the diet of *R. sordidus* consists mainly of vegetation and seed, with a small, but consistent, proportion of insects (Watts 1977; Watts and Aslin 1981). In sugarcane growing areas, *R. sordidus* has extended its diet to include sugarcane (Woods 1966).

Populations of *R. sordidus* in canegrowing regions cycle annually with the crop cycle. The amplitude of the cycle is dependant upon environmental conditions that dictate breeding success and mortality (Allsopp et al. 1993). The well-defined breeding season starts each year between November and March. The onset of breeding is associated with a flush of grass and weed growth in and around crops. Breeding intensity peaks 1-2 months after the onset of pregnancies and declines rapidly thereafter. Breeding ceases around July, regardless of climatic conditions. Populations then disperse and decline with crop harvest (Wilson and Whisson 1989).

### 2.2 History of rodent control practices in Queensland sugarcane

The annual reinvasion of canefields by *R. sordidus* is the key to the control of damage to cane. Agricultural practices to reduce colonisation of sugarcane crops by rodents are therefore vital. All control strategies can be classified as to whether they reduce immigration, increase mortality or reduce reproduction (Stenseth 1981). If the mortality rate
is high in uncontrolled populations, the reduction of reproduction is likely to be the optimal type of pest control (Krebs 1985). Wilson and Whisson (1993) demonstrated that reducing the reproductive potentials of *R. sordidus* populations by limiting the essential food source required for the onset of breeding (in-crop weeds), crop damage could be reduced by up to 60%.

Biological control of rats seems to be negligible. Rodents are subject to attack from diseases, parasites and predators. In most sugarcane growing areas, mammals, birds and reptiles are predators of rodents. Introduction of specific strains of *Salmonella* sp. has been considered as controls (Bates 1969).

Despite the long history of rodent outbreaks and the severity and importance of rodent damage, most rodent control programs have been haphazard and did not provide long-term, cost-effective population control (Davis and Jackson 1982). Methods, often chemical, attempted to control populations once damage had occurred. Such damage had already been inflicted and populations were large and reproductively active. Control programs were not aimed at preventing the problem, but rather attempted to cure the symptoms.

Early research on rodent control in Queensland centred on rodenticide evaluation. Laboratory studies by McDougall (1944c) evaluated poisons and bait bases for rodents in sugarcane. Whole grain such as wheat and oats were the most efficient bait bases and thallium sulfate and yellow phosphorous were 'suitable poisons'.

In Queensland sugarcane fields before 1990, the acute rodenticide thallium sulfate was aerially distributed for the control of *R. sordidus* and *M. burtoni*. It was usually applied in autumn and/or winter. This was not an effective control strategy because:

- Baits were applied in response to an increase in damage at the end of the breeding season. Wilson (1983) showed that rodenticides can only provide effective control if breeding potential is suppressed and if baits are applied in anticipation of future damage.

- Because rodent damage within canefields is largely sporadic and localised, aerial baiting entire districts is costly and unselective with a large portion of baits falling in areas with low rodent populations (Taylor 1972; Redhead and Saunders 1980).

- Poisoned animals are rapidly replaced by others from neighbouring fields acting as reservoirs between rodenticide applications. This is aided by the staggered harvest of sugarcane. At the time of thallium sulfate application in mid-winter, the breeding cycle was virtually complete and rodent populations were dispersing (Redhead and Saunders 1980; Whisson and Delaney 1989).

- Thallium sulfate, while being effective against the target species, is also toxic to non-target vertebrates.

McDougall (1947) stated that 'on present knowledge, collective poisoning campaigns and attacks on rat populations as a whole are not of primary importance in lessening rat damage
in Queensland cane fields'. He also noted that baiting in some districts had been carried out for so many years that it had become a routine on-farm practice rather than a strategic rodent control mechanism. He recognised that rodent populations in Queensland sugarcane have 'periods of movement'. This dispersal phase of the rodents' population cycle commenced at the time baiting programs were attempted and thought to have been successful. Wilson and Whisson (1989) documented this decline in rodent population densities in sugarcane as a natural decline seen each year due to the cessation of the breeding cycle and not as a result of baiting campaigns. McDougall (1947) also documented this annual, natural decline in population densities and drew similar conclusions, as well as identifying appropriate times for strategic baiting.

In 1990 the registration of thallium sulfate was discontinued. The second-generation anticoagulant rodenticide brodifacoum was then introduced under the trade name Klerat (Story 1993).

### 2.3 Brodifacoum

Brodifacoum is of exceptional potency and is capable of controlling rodents resistant to first-generation anticoagulant poisons. Solitary as well as commensal species are controlled by brodifacoum. Adequate control is obtained from 50 mg kg$^{-1}$ in a single feeding for most species and, in contrast to other acute rodenticides, symptoms are delayed and no bait shyness is evident (Anon. 1990). Brodifacoum is effective against a wide variety of rodents including warfarin-resistant species (Redfern et al. 1976). Brodifacoum and thallium sulfate were compared in trials in north Queensland sugarcane fields (Hitchcock et al. 1983). Wheat baits treated with brodifacoum (0.005%) and thallium sulfate (0.3%) were applied at 1.68 kg ha$^{-1}$ and were equally effective in reducing damage. Wilson (1989) showed that the toxicity of thallium sulfate to *R. sordidus* in no-choice feeding trials was not significantly different to that of brodifacoum. However, when animals were given a choice between rodenticide and an alternative food source, brodifacoum was significantly more effective than thallium sulfate.

Brodifacoum, marketed in Australia under the trade name Klerat, was assessed for its efficacy in north Queensland sugarcane. The provisionally recommended rate of 2 kg ha$^{-1}$ offered the best short term population control when compared with 4 and 1.5 kg ha$^{-1}$, although baiting at all rates reduced crop damage (Story 1993).
2.4 Integrated Pest Management for rodents in sugarcane

The development of integrated pest management (IPM) programs have become common during the last 10-15 years both in vertebrate and invertebrate population management. An IPM program incorporates biological, cultural and chemical control procedures implemented in an orderly sequence (Krebs 1985) in an attempt to prevent populations increasing, rather than applying control measures after crop damage has occurred. The practical implementation of IPM strategies are proving far more difficult to achieve (Norton and Mumford 1993). The development of more effective poisons has an important role in IPM. However, successful rodent management will make maximum use of habitat manipulation techniques already developed. In management of sugarcane rodents, the most efficient and cost-effective way to minimise crop losses is to prevent an increase of population densities, rather than attempting to control or reduce numbers once they have increased (Wilson and Whisson 1989).

Research into *R. sordidus* populations in Queensland sugarcane has emphasised the importance of cultural controls in reducing the reproductive potential of rodent populations. The role of habitat manipulation techniques in the suppression of the canefield rat breeding cycle is critical if losses are to be minimised. An integrated pest management program has been devised for this species in Queensland sugarcane that emphasises habitat manipulation techniques such as in-crop weed control, non-crop habitat manipulation and farm hygiene. Damage reductions of up to 60% can be attained (Wilson and Whisson 1989).

Habitat manipulation uses both cultural and chemical control methods in an orderly sequence based on an understanding of the population dynamics of the target species (Wilson 1989). The chemical control methods for rodents in sugarcane can either be in the form of herbicide treatment to reduce weed and grass biomass, or in the form of rodenticide application at strategic times during the population cycle of the pest. Cultural controls include mowing or close grazing of non-crop grassland and/or replacement of grassland or open woodland with closed forest. Habitat manipulation is an unspectacular method for rodent control. It does not have the political and psychological advantage of direct kill methods.

Wilson and Whisson (1989) outlined IPM employing habitat manipulation techniques designed to reduce rodent damage by *R. sordidus* in northern Queensland sugarcane. This program addressed three main areas within the sugarcane production system with separate responsibilities for growers, industry and research and development.

Grower responsibilities centred on biological and cultural control aspects such as farm hygiene, in-crop weed control and the mowing, grazing or removal of non-crop refuges designed to reduce the breeding potential of colonising *R. sordidus* populations in canefields.

Regional responsibilities include the prediction of rodent incidence and crop damage and defining optimum periods for additional action such as strategic baiting campaigns. The aim of the regional responsibilities is to reduce the reliance on rodenticides as well as modelling population dynamics on a wider scale to develop correlations between population densities, crop damage and environmental
parameters such as rainfall. Critical periods for management need to be precisely estimated so pressure can be applied to populations when densities are low thus enhancing control and minimising environmental risks.

Industry responsibilities involve the provision of expertise to establish early warning systems through predictive modelling and interpreting this information. Recommendations are then made to the industry concerning action needed to address the damage potential within each canegrowing region.

3.0 PROJECT OBJECTIVES

The objectives of this project (BS78S) were to determine the optimum time for rodenticide application, to quantify the effectiveness of weed control in crops, and to quantify strategic bait application in reducing damage to sugarcane from rodent attack. These rodent management strategies were evaluated in the absence of non-crop habitat manipulation techniques which are also recommended as components of the IPM package for *R. sordidus* in sugarcane.

**Phase One:** Assess the optimum time for application of Klerat baits to reduce the breeding potential of rodent populations and subsequent crop damage.

**Phase Two:** Integrate baiting strategies using Klerat with the existing in-crop weed-control program for rodent control in sugarcane.

4.0 METHODS AND MATERIALS

4.1 Phase One: Identification of optimum bait application time

Four treatments, replicated 15 times, giving a total of 60 trial plots, were located in the Herbert Valley canegrowing district for this trial. Plots were approximately 2 ha, at least 250 m from the nearest non-crop harbourage and selected on the basis of previous rodent damage, farmer cooperation and similarity in soil type and sugarcane age.

The four treatments were:

- Baiting at the start of the *R. sordidus* breeding cycle using Klerat at 2 kg ha$^{-1}$;
- Baiting late in the *R. sordidus* breeding cycle using Klerat at 2 kg ha$^{-1}$ (when rodenticide application has occurred historically);
- Baiting, using Klerat at 1 kg ha$^{-1}$, at both the above times;
- Control - no bait applied.

Four 5-g Klerat wax blocks were applied at each corner of a 10-m$^2$ grid (ie four bait locations would occur in a 10-m$^2$ grid). Where rodenticide application was 1 kg ha$^{-1}$, only two wax blocks were applied at each bait location.
4.1.1 Rodent population census

Rodent population densities were monitored monthly from February 1993 to June 1993 on 15 replicates used in the trial. 40 Elliott, Type A, medium live traps were set in each plot. Traps were arranged in a grid comprising four lines of 10 traps, each trap 10 m apart and each line 10 cane rows (approximately 15 m apart).

Cardboard squares soaked in linseed oil were used as bait. Traps were rebaited only if they caught rodents the previous night. Animals caught were measured, sexed and tagged by toe clipping and released at the point of capture.

The population census ceased in June 1993 as *R. sordidus* population monitoring within the Herbert Valley indicated that the annual population dispersal had commenced. Therefore random redistribution of *R. sordidus* individuals meant that numbers of rodent within trial sites would be influenced by migrating animals.

Data for each month of census were analysed using either a factorial analysis of variance with least squares means or a randomised complete-block design with least squares means, depending on the proportion of missing values. Due to the non-linear nature of the relationship between capture frequency and index for rodent populations in sugarcane, rodent capture frequencies were transformed to density indices using the transformation $x=-\ln(1-f)$, where $f$=capture frequency and $x$=density index (Caughley 1977).

4.1.2 Crop damage and in-crop weed-biomass assessments

Five sampling points, each comprising two paired, fixed-length transects were distributed evenly throughout each trial site, to give the 100 cane stalks per transect. Counts were performed from February 1993, when the first millable cane appeared on cane plants, and continued each month until June 1993.

Sampling for crop damage and weed biomass ceased in June 1993 as *R. sordidus* population monitoring within the Herbert Valley indicated that the annual population dispersal had commenced. Therefore, random redistribution of *R. sordidus* individuals meant that damage occurring in canefields after June could not be directly linked solely to treatment effects.

Weed biomass was determined by estimating percentage green cover between each paired damage transect.

Crop damage data were analysed using the randomised complete-block design.

4.2 Phase Two: Integration of Klerat into the IPM program for *Rattus sordidus* in sugarcane

Four treatments, each replicated 15 times, giving a total of 60 trial sites, were located in the Herbert Valley canegrowing district in the same way as in Phase One.
The following treatments were assessed:

- Baiting at 2 kg ha\(^{-1}\) at the start of the \textit{R. sordidus} breeding cycle and herbicide application to control weeds;
- Baiting at 2 kg ha\(^{-1}\) at the start of the \textit{R. sordidus} breeding cycle only;
- Herbicide application to control weeds;
- Control - no bait or herbicide applied.

Treatments were randomly allocated within each of the 15 replicates. Rodenticide was applied as in Phase One. Herbicide application was undertaken by a contractor using chemicals recommended by BSES extension officers at recommended rates after an initial inspection of trial sites to identify weed species present, growth stage and vigour.

### 4.2.1 Rodent population census

Rodent population densities were monitored each month from November 1993 to July 1994 as in Phase One.

### 4.2.2 Crop damage and in-crop weed-biomass assessments

Rodent damage to sugarcane and weed biomass were measured each month from February 1994 until July 1994. Data were analysed as in Phase One.

### 5.0 RESULTS

#### 5.1 Phase One. Optimum rodenticide application time

##### 5.1.1 Crop damage

The highest preharvest damage level was recorded in the split rodenticide application of 1 kg ha\(^{-1}\) in January/April; this was followed by the control (Fig. 1). Applications of 2 kg ha\(^{-1}\) in January or April showed no differences in preharvest crop damage levels. There were no significant differences between any treatments in preharvest crop damage.

##### 5.1.2 Rodent population census

Despite a population decline in all treatments between February and March, attributed to the effect of dry weather on weed growth (Figs 3-7), a treatment effect was observed in canefields where rodenticide was applied in January (Fig. 2). Application of 2 kg ha\(^{-1}\) in January had the greatest effect on overall population levels. Bait applied at 1 kg ha\(^{-1}\) in January and again in April reduced population levels between February and March, but had little effect on rodent numbers between April and May.

Weed biomass peaked in February, and this was followed almost immediately by the appearance of immature rodents in all populations (Figs 3-6), signifying that breeding had commenced. Although population levels declined markedly with the application of
rodenticide, breeding continued and numbers increased by June. Therefore, constant juvenile recruitment into the population allowed rapid replacement of poisoned rodents.

The occurrence of recaptured rodents generally declined after March due to the influx of new individuals from neighbouring canefields and juvenile recruitment from within the population being sampled (Fig. 7). Recaptures increased between February and March in all treatments except the split application (January and April at 1 kg ha\(^{-1}\)) and declined thereafter. It is unclear how much of this decline can be attributed to rodenticide application. Weed biomass also declined during this time in all treatments.

There were no significant \( (P < 0.222) \) differences in population estimates detected between treatments for Phase 1 of this trial.

5.2 Phase Two. Integration of Klerat into the IPM program for *R. sordidus*

5.2.1 Crop damage

Crop damage assessments started 1 month earlier than in Phase One due to the earlier occurrence of millable cane. Rodent damage to sugarcane declined in the control treatment between February and March (Fig. 8). This was due to cane stools reshooting and replacing early shoots counted as damaged in February.

The unweeded and the unbaited (control) treatments recorded highest damage levels in February at the start of damage sampling, while the weeded and baited treatment recorded a significantly lower damage level \( (P = 0.0075) \). This was the only month in which significant differences in damage counts were detected \( (P = 0.206) \) (Fig. 8). Treatments in which herbicide was applied had lower damage levels than baited-only treatments, despite no significant differences being detected each month between treatments. The decline in percent crop damage between May and June can be attributed to damage sampling being conducted late in June after the commencement of the harvest season with a number of heavily damaged replicates being cut in the first round of harvesting.

5.2.2 Rodent population census

Statistical differences in rodent populations were only evident in November 1993 when sampling commenced and in June 1994 (Table 3; Fig. 9). No significant statistical differences in rodent population densities were evident immediately after treatment.

Unweeded and unbaited canefields showed the highest peak in rodent numbers while the weeded and baited fields showed the lowest population levels after treatment (Fig. 9). However these differences were not sustained, probably because of immigration from neighbouring canefields and the resurgence of weed biomass levels.

The control (unweeded and unbaited) maintained consistent weed biomass levels, showed two stages of juvenile recruitment and a constant mature strata (Fig. 10). The gap in juvenile recruitment between January and April may be partially due to the effects of widespread flooding in the Herbert Valley in February 1994. The unweeded and baited treatment showed a decline in population density after baiting (Fig. 11). It is unclear how much of this
decline is due to bait application and how much is due to flooding. However the consistent weed level allowed populations to re-establish quickly and juvenile recruitment resumed in April.

Table 3

Significant differences in rodent population densities during Phase Two

<table>
<thead>
<tr>
<th>Time</th>
<th>Treatment</th>
<th>Mean rodent population density index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 1993</td>
<td>Unweeded/unbaited</td>
<td>0.150\textsuperscript{a}</td>
</tr>
<tr>
<td></td>
<td>Weeded/baited</td>
<td>0.290\textsuperscript{ab}</td>
</tr>
<tr>
<td></td>
<td>Unweeded/baited</td>
<td>0.345\textsuperscript{ab}</td>
</tr>
<tr>
<td></td>
<td>Weeded/unbaited</td>
<td>0.401\textsuperscript{b}</td>
</tr>
<tr>
<td>June 1994</td>
<td>Unweeded/unbaited</td>
<td>0.535\textsuperscript{a}</td>
</tr>
<tr>
<td></td>
<td>Unweeded/baited</td>
<td>0.365\textsuperscript{ab}</td>
</tr>
<tr>
<td></td>
<td>Weeded/unbaited</td>
<td>0.350\textsuperscript{ab}</td>
</tr>
<tr>
<td></td>
<td>Weeded/baited</td>
<td>0.290\textsuperscript{b}</td>
</tr>
</tbody>
</table>

*Rodent population indices followed by the same superscript are not significantly different at the 5% level.

The application of herbicide at the beginning of the rodent breeding season without rodenticide use, reduced weed biomass levels and rodent populations (Fig. 12). Flooding in the Herbert Valley in February also affected these weed and rodent populations. The decline in rodent populations is larger in the treatments than in the control and so treatment may be affecting population density. The largest effect of treatment was seen in the weeded and baited replicates where no rodents were caught in February (Fig. 13). Flood conditions in February saw weed growth resume and this enabled immigrating rodents to recommence breeding.

Recapture frequencies, expressed as a proportion of the total sample size, were relatively consistent over time except for the unweeded/baited and the weeded/baited treatments where a decline in recaptured rodents occurred between January and March (Fig. 14).

6.0 DISCUSSION

6.1 Phase One: Optimum time for rodenticide application

Crop damage results between treatments were inconclusive in that no significant differences were detected by June. This contrasts with population data given in Figs 2-7 which indicated
that baiting reduced population density when rodenticide was applied in January, early in the breeding cycle of *R. sordidus* and before crop damage was evident. Rodenticide application in April, after breeding had started, was not effective in reducing rodent population density.

A decline in weed biomass due to dry conditions experienced in February 1993 led to a small decrease in the *R. sordidus* population in the control (Fig. 3). This decrease was also evident in the April treatment (Fig. 5) before rodenticide was applied. This decline in rodent population density was larger in canefields baited in January (Figs 4 and 6) indicating an effect that can be attributed to rodenticide application. Baiting canefields with 2 kg ha\(^{-1}\) in January, which in 1993 marked the commencement of the *R. sordidus* breeding cycle, gave the largest population decrease. Baiting when populations are small, before, or as breeding commences (McDougall 1946b; Wilson and Whisson 1993) maximises effective bait consumption by a significant proportion of the population. This is because the commensal nature of *R. sordidus* populations (Watts and Aslin 1981) leads to a social structure that allows for dominant individuals to preferentially forage and ‘over consume’ rodenticide. This denies less dominant rodents, which comprise a large proportion of the population later in the population cycle, access to rodenticide reducing their chance of poisoning. A small section of the population will be exposed to the bait at any one time. The start of the *R. sordidus* breeding cycle is therefore a strategic ‘window’ in the population cycle of *R. sordidus* through which a management strategy can be applied.

The continued availability of in-crop weeds after bait application allowed the recruitment of juveniles into the population. Therefore, rodent densities increased after bait application as weed control was not conducted. This was observed in all treatments after bait application, although the degree to which populations resumed breeding varied between treatment.

*R. sordidus* population dynamics occur on a regional scale and not on an individual farm basis. Therefore current strategies of treating problems in an individual farm manner is not effective. Population recruitment can occur from neighbouring canefields or from within the same field if weed control is ineffective. Fig. 7 gives levels of recaptures between treatments which indicate population structure. Recapture rates show that significant *R. sordidus* recruitment occurs after bait application. This recruitment was documented by Wilson and Whisson (1993) as due to a resurgence in rodent breeding triggered by the presence of in-crop weeds until the breeding season ceases in June/July. At this time the appearance of new captures in population census can be attributed to a random and forced population redistribution brought about by migration and a staggered sugarcane harvest.

The occurrence of recaptures declined rapidly in all treatments after bait application except the split application treatment (January/April baiting) where the population always contained a majority of new individuals (Fig. 7). This rapid decline in recaptured individuals suggests that dominant individuals were removed by the rodenticide. It is evident that a very effective recruitment mechanism is available to rodent populations in sugarcane on a regional scale. Therefore this aspect must be addressed on a regional level for management to be successful.

### 6.2 Phase Two: Integration of Klerat into the IPM program for *R. sordidus* control in sugarcane
Crop damage results were inconclusive (Fig. 8), with no significant differences detected between treatments at the final preharvest count. A decline in crop damage was observed between the June and July sampling points. This can be explained by a number of heavily damaged trial sites being harvested in the first round of the 1994 cane harvest season, thereby decreasing the mean crop damage level for treatments.

Overall capture densities (Fig. 9) show the maximum decrease in population levels was achieved by the combination of herbicide and rodenticide application. Baiting without herbicide application and herbicide application without baiting also offered a limited level of population reduction. Populations were reduced in the untreated controls, possibly due to flooding in February 1994.

The joint effect of herbicide and rodenticide was evident when population structure was examined over time (Figs 10-13). The age-class structure of populations in control fields (Fig. 10) reveals that a steady population density was maintained from January to May after an initial decline. This corresponded to consistent weed biomass levels and was followed by a peak population density of all strata within the population in June. The peak population in June follows a peak weed biomass level in May and conforms to population trends identified by Wilson and Whisson (1993). Juvenile recruitment is detected between November and January and again between April and July when sampling ceased.

Canefields subjected to bait application only (Fig. 11), showed a decrease in mature and immature rodents until February when the mature class began to increase. Juvenile recruitment resumed in March, only four weeks after minimum population density was reached and 9 weeks after rodenticide was applied. This corresponded with a increase in weed biomass from January to May.

Applying herbicide to canefields reduced rodent populations (Figs 12-13) in line with declines in weed biomass. Fig. 12 shows a decline in population densities in January and February after herbicide application and indicates a lag phase of some 3-4 weeks between in-crop weed control and population decline. Juveniles re-entered the population samples in April as weed biomass increased. There was a dramatic decline in *R. sordidus* populations subjected to rodenticide and herbicide application early in the breeding cycle (Fig. 13). Population levels were reduced to zero in February probably due to a combination of large decrease in weed biomass, rodenticide removing dominant individuals, and flooding in February 1994. However, by March re-invasion had occurred, indicating that movements between canefields documented by McDougall (1946a) and Wilson and Whisson (1993) may occur whenever populations increase to a level where subadult rodents must emigrate to establish home ranges in which to forage. This contrasts with the view expressed by Wilson and Whisson (1993) which indicated that a dispersal phase commences at the cessation of the breeding cycle around June/July.

### 7.0 CONCLUSIONS

Phase One (timing of baiting), showed that while rodent populations can be influenced by
rodenticide application, canefields are reinvaded readily by rodents and rodenticide application alone had no effect on crop damage at harvest. Phase Two (weeding and/or baiting) indicated that implementing two components of the IPM package was also insufficient to rodent damage. While herbicide and rodenticide application together reduce rodent populations, re-establishment of weeds led to reinvasion and breeding by rodents. Rodent management can only be successful if regional IPM programs aimed at reducing the reproductive potential of rodents are adopted. *R. sordidus* populations function on a regional scale (Wilson and Whisson 1993; Story 1993) and therefore rodent management programs must also be regional. The entire IPM package, including manipulation of noncrop habitats to reduce refuges of rodents, must be implemented. Partial implementation is insufficient for crop damage reduction.

The current approach to treat rodent problems on a ‘per farm, per paddock’ basis is insufficient for crop loss reduction. Clearly, untreated areas such as refuges and farms where weed control is inadequate harbour rodents which then reinvade treated areas. Such areas must be targeted by research and extension exercises to encourage improvements in farm management. Revegetation of noncropped areas, improvement in farm hygiene, increased levels of weed control, monitoring of rodent numbers and breeding status, and strategic baiting together make up the IPM package and must be implemented as a package to reduce financial losses caused by rodents.

8.0 ACKNOWLEDGMENTS

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9.0 REFERENCES


with emphasis on the ecology and reproduction of Melomys littoralis Lonnberg). MSc Thesis, James Cook University.


Figure 1. Mean percent crop damage per treatment for Phase 1
Figure 2. Overall transformed rodent capture densities for Phase 1 baiting treatments
Figure 3. Distribution of mature and immature rodents and mean weed biomass levels per month for untreated plots in Phase 1
Figure 4. Distribution of mature and immature rodents and mean weed biomass levels per month for the January-baited treatment in Phase 1
Figure 5. Distribution of mature and immature rodents and mean weed biomass levels per month for April-baited treatments for Phase 1
Figure 6. Distribution of mature and immature rodents and mean weed biomass levels per month for split application of baits in Phase 1.
Figure 7. Recapture frequency as a proportion of total population per treatment over time for Phase 1 baiting treatments applied at different times.
Figure 8. Mean percent crop damage per treatment for Phase 2 (baiting and/or weeding)
Figure 9. Overall transformed rodent capture densities per treatment for Phase 2 (baiting and/or weeding)
Figure 10. Distribution of mature and immature rodents and mean weed biomass levels per month for the control treatment in Phase 2
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