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INTEGRATED PEST MANAGEMENT OF SOLDIER FLY

by

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ABSTRACT

Soldier flies are a serious soil-dwelling pest of cane, and there is no insecticidal control available. In large-plot trials, numbers of soldier fly larvae in plant and first ratoon crops were lower after a long fallow, with old crops destroyed early in the harvest season and new crops planted late the following year, than after a short fallow with late crop destruction and early planting. This difference was not maintained in older ratoons in the trials, but that may not be so if long fallowing was implemented on a larger scale. Two long fallowing methods, either using herbicide to kill old crops and weeds or growing soybeans, were at least as effective as bare fallowing with frequent cultivation, the previously recommended cultural control procedure for the pest. These methods are now recommended for soldier fly management. Various other procedures were tested for killing soldier fly larvae in fallows – rotary hoeing, application of a biocide (metam-sodium), combination of a systemic pesticide (carbofuran) with a lure crop (sorghum), and growing brassica break crops – but these either did not control soldier flies or failed for other reasons. The annual addition of organic matter to crops as either a green-cane trash blanket or mill mud did not change the soldier fly status of fields within a crop cycle. Long fallowing by appropriate means is the best way of minimising the risk of damaging soldier fly populations in young ratoon crops, although at the cost of reduced plant crop yields due to a shortened growing period.

SUMMARY

Seven long-term trials, six in southern Queensland and one at Mackay, were established to compare the effect of various fallow and crop management procedures on populations of soldier fly and potential natural enemies over a crop cycle.

Six farming practices were compared; a short fallow, a short fallow plus mill mud, a short fallow plus a green-cane trash blanket in ratoons, a long bare fallow with frequent cultivation, a long fallow under sugarcane trash with sprayout of old stools and minimum tillage, and a long fallow with a soybean rotation followed by minimum-tillage planting. Fallows were lengthened by both destroying old crops earlier than usual and planting late. It was hoped that minimum tillage would help to preserve natural enemies of soldier fly from the old crop, and that other treatments such as mill mud and trash blanketing would encourage the increase of natural enemies in fields. Treatment plots were large, about 0.2 ha each, to minimise movement of soldier flies or other fauna between plots.

The long fallow treatments greatly reduced numbers of soldier fly larvae in new plant crops in comparison with numbers in the old crops. This reduction was not dependent on cultivation for soldier fly control, and an equally good result was achieved by spraying out the old crop with glyphosate and controlling weeds with herbicide, or by growing a crop of soybean in rotation. A short fallow also reduced numbers of larvae, but about 1% still carried over into the new plant crop. Fewer larvae were found in plant crops and first ratoons after a long fallow than in the short fallow treatments. This difference was perhaps maintained into the second ratoon, but by the third ratoon there was no difference between fallow lengths. It is possible that there may have been migration of adults between plots, and if so, the effect of late planting may be longer-lasting if carried out over whole fields.

Zero-tillage of herbicide-sprayed fields preserved levels of the insect pathogen *Metarhizium anisopliae* in the new sugarcane rows, but did not appear to affect the abundance of other groups of beneficial fauna. Addition of organic matter as trash or mill mud did not seem to increase the density of predators, although earthworm densities were increased, particularly by mill mud.

Of the potential predators examined, past emphasis has mainly been on coleopterous (beetle) predators such as carabids, staphylinids and wireworms. There was little evidence that a difference in the population densities of these predators between fields was a critical factor determining soldier fly densities in the trials in southern Queensland. This may not be so everywhere; many pupal cases from the old crop in the trial at Mackay showed damage consistent with invertebrate predation, perhaps by beetles or beetle larvae, and the soldier fly population in the new crop remained at a low level at this site. The trials suggest that ants, which are very abundant in many canefields, may have a more important role than previously thought. Ant densities in second ratoons appeared to be related to the fallowing history of fields, but more research would be required to substantiate this.

There was no evidence that organochlorine levels are influencing soldier fly population dynamics on these farms. Levels of dieldrin and BHC were mostly low, and heavy infestations of soldier fly were recorded on farms with various residue levels. Correlations were found between soldier fly densities and levels of some nutrients in soil. These correlations may be spurious, but some could be worthy of further investigation in controlled experiments.

Cane yields over a crop cycle of a plant crop and two ratoons were consistently lower where cane was planted late after a long fallow than where it was planted early. Different planters were used for each planting time, but the main reason for the difference in yields was the longer growing time of the plant crop that was planted early. Lower soldier fly populations in late-planted cane did not negate this initial handicap.

In addition to the long-term trials, a series of short-term trials was carried out to evaluate alternative methods of managing fallows to prevent soldier fly larvae from carrying over into new crops. Targeting of larvae by rotary hoeing did not cause any additional larval mortality compared with discing and ploughing. The soil fumigant Vapam (metam-sodium) reduced larval numbers by about 70% when injected beneath ratoon stools after the soil in the old rows was first cultivated with a rotary hoe and then sealed immediately following application using a roller and irrigation. Use of Furadan (carbofuran), a systemic pesticide with known activity against soldier fly, in combination with sorghum to attract soldier fly larvae into the toxic zone, did not reduce larval numbers. No evidence was found that any of eighteen potential break crops, including 13 brassica lines, were directly toxic to larvae. Several lines of Indian mustard (Fumus) and rape (BQMulch™) were tested as break crops in field plots near Bundaberg. However, they grew extremely poorly when planted in November. When cane was killed with herbicide in a trial at Mackay, soldier fly populations fell by 98% from November to the following June. This level of soldier fly reduction suggests that farmers do not need severe treatments such as soil fumigation if they are willing to delay planting to starve larvae.

In summary, long fallowing by combining crop destruction early in the harvest season with planting late the following year was effective in reducing soldier fly numbers in plant and early ratoon crops. Early crop destruction is not popular with cane farmers, who prefer to wait until all fields have been harvested before deciding which crops to destroy. However, late planting is acceptable to farmers with soldier fly problems and many have already adopted the practice. There was a cost to late planting in the trials, due to reduced yields of the plant crop caused by the shorter growing period. However, some crops affected by soldier fly can fail to ratoon after only one or two harvests, if no preventative steps are taken. Late planting with or without early crop destruction should avoid the possibility of crop failures in young ratoons, and is one way of reducing risk in soldier fly prone fields, with either spraying out using herbicide or rotation with soybeans being the preferred options. Crop management procedures to minimise the subsequent rate of increase of soldier fly populations have still not been identified.

1.0 BACKGROUND

The area of sugarcane infested by soldier flies showed an alarming increase during the 1990s, with many new infestations reported in fields at Mackay and severe damage recorded at Ayr where the pest has never previously been seen. Losses in 1994 were recorded as costing almost $1m to the industry, and losses in 1995 were higher again. Even these figures underestimate the pest's importance (see section 4.1). Recorded losses refer to patches within fields that show dramatically poor ratooning, and ignore the insidious reduction in yield that soldier fly infestation may cause over a whole field. In addition, the cost of soldier fly losses is not spread evenly through the industry, but impacts heavily on a smaller number of farms whose viability is threatened by the pest. The lack of a reliable control method leaves the industry open to a rapid increase in losses. Although the existing (1995) cultural control recommendation of a bare fallow with hard cultivation seems to give short-term relief, soldier fly often reappear in early ratoons. Bare fallowing is inappropriate in many areas, especially at Mackay and Ayr, because of the risk of erosion. Growers need alternative management strategies.

This project aims to develop farming practices that provide long-term suppression of soldier fly, for inclusion in an integrated pest management program. Pest research has shown that natural enemies can inhibit the build up of soldier fly populations. Growers presently (1995) rely heavily on cultural control methods that include long fallowing and cultivation to kill larvae before planting. However, this provides no protection against the subsequent development of infestations, and may even encourage build-up of soldier fly by killing natural mortality agents in the soil. Long-term suppression of soldier fly may be better achieved by encouraging pathogens and natural enemies using sustainable farming practices that are the opposite of disruptive cultivation.

2.0 OBJECTIVES

(1) Establish experimental sites comparing farming practices, developed in consultation with growers, that are intended to reduce soldier fly numbers by encouraging natural enemies.

(2) Measure the number of soldier fly that survive from ploughout into the newly planted cane, and measure rates of population increase in subsequent ratoons, under the different practices.

(3) Measure the effect of the different practices on natural enemies and *Metarhizium*, and use this information to interpret changes in the soldier fly population.

(4) Investigate, as alternatives to a long bare fallow and cultivation, disinfestation procedures based on strategic cultivation, break crops or judicious use of chemicals, that are equally or more effective and that are more acceptable to growers.

(5) Devise an integrated control program for soldier fly and extend to growers.

3.0 OUTCOMES AND OBJECTIVES

(1) Establish experimental sites comparing farming practices, developed in consultation with growers, that are intended to reduce soldier fly numbers by encouraging natural enemies.

Six farming practices were identified after grower meetings in 1995.

1. Short fallow, local standard management.
2. Short fallow as above, plus mill mud.
3. Short fallow as above, plus trash blanket in future ratoons.
4. Long fallow, with frequent working of bare fallow for soldier fly control (BSES recommendation at that time).
5. Long fallow, with soybean rotation and minimum-tillage planting into soybean stubble.
6. Long fallow, with sprayout of old ratoon and minimum-tillage planting into old sugarcane rows.

It was hoped that minimum tillage between crop cycles would preserve natural enemies from the old crop, organic matter supplied as cane trash or mill mud would encourage decomposers to provide alternative food for generalist predators that could also feed on soldier fly, and a green-cane trash blanket might also provide a suitable habitat for predators such as beetles on the soil surface.

Eight sites were established before destruction of the old crop, but one was lost during the fallow period. Treatment plots were large, about 0.2 ha each, to minimise movement of soldier flies or predators between plots.

(2) Measure the number of soldier fly that survive from ploughout into the newly planted cane, and measure rates of population increase in subsequent ratoons, under the different practices.

Numbers of soldier fly were measured before destruction of the old ratoons in 1995, by collecting samples of four soil cores from around each of 10 stools near the centre of each treatment plot. Numbers of soldier fly in the newly planted cane were then measured early in 1997 and annually thereafter, with the last sample taken in the young third ratoon.

A long fallow, combining early crop destruction with late planting, resulted in fewer soldier fly larvae in plant, first and perhaps second ratoon crops than a short fallow. However, no difference was found between fallow lengths in the third ratoon, perhaps reflecting a change in soldier fly dynamics within each plot but perhaps also indicating migration of adult flies between plots. There was no significant effect of the different treatments within each fallow length on solder fly numbers.

(3) Measure the effect of the different practices on natural enemies and *Metarhizium*, and use this information to interpret changes in the soldier fly population.

Minimum-tillage planting after sprayout of old ratoons resulted in higher levels of *Metarhizium* in the new plant cane rows than did conventional ground preparation. However, *Metarhizium* was not a significant factor affecting the soldier fly population. The different practices had no significant effect on known natural enemies, mainly wireworms, carabids and staphylinids. Numbers of ants differed between fallow lengths in the second ratoon, but the role of ants is unknown. Numbers of earthworms increased with the addition of organic matter, particularly mill mud, but this appeared to have no effect on natural enemies or indirectly on soldier fly.

(4) Investigate, as alternatives to a long bare fallow and cultivation, disinfestation procedures based on strategic cultivation, break crops or judicious use of chemicals, that are equally or more effective and that are more acceptable to growers.

Rotary hoeing of stools at the time of crop destruction caused no more harm to larvae than more gentle cultivation implements. The soil fumigant Vapam (metam-sodium) reduced larval numbers by about 70% when injected beneath ratoon stools after the soil in the old rows was first cultivated with a rotary hoe and then sealed immediately following application using a roller and irrigation. Use of Furadan (carbofuran), a systemic pesticide with known activity against soldier fly, in combination with sorghum to attract soldier fly larvae into the toxic zone, did not reduce larval numbers. No evidence was found that any of eighteen potential break crops, including 13 brassica lines, were directly toxic to larvae in pot trials. Several lines of Indian mustard (Fumus) and rape (BQMulch™) grew extremely poorly when planted in field plots near Bundaberg in November, and the potential of brassicas may be limited by their agronomic requirements. When stools were killed with herbicide, soldier fly populations fell by 98% from November to the following June, and no larvae were found in the new plant crop. This agrees with results of the long-term trials of farming practices. This level of soldier fly reduction suggests that farmers do not need severe treatments such as soil fumigation if they are willing to delay planting to starve larvae. A rapid method of disinfesting fallows was not found.

(5) Devise an integrated control program for soldier fly and extend to growers.

Long fallowing is being recommended for soldier fly management, by combining early crop destruction with late planting. A long fallow is needed because larvae take many months to starve. Early crop destruction also removes the food source while larvae are small and vulnerable, and late planting ensures that no crop is present when adults are flying in April-June. The break period should be kept free of suitable grass hosts, either by killing the old crop and grass weeds with herbicide or by planting a non-grass cover crop such as soybean. Retention of trash from the old crop will help suppress grass if a herbicide fallow is chosen. Cultivation during the break should be minimised to conserve natural enemies. Varieties that ratoon quickly should be chosen for planting. The valuable crops, ie plant and young ratoons, should be harvested when ratooning conditions are good, perhaps mid-season, to give them the best chance of ratooning if soldier fly are present. A brochure based on these recommendations is attached as Appendix I.

A yield benefit from long fallowing was not demonstrated in my trials, and in fact the opposite was the case. Long fallowing is a way of reducing risk; ratoon failures early in the crop cycle should not occur if these procedures are followed, but whether this is justified will depend on the risk assessment of each farmer. I also could not demonstrate that reduced tillage helps conserve natural enemies, apart from *Metarhizium* which is not usually a significant factor in soldier fly populations, but intuitively this approach is attractive. Reduced tillage of fallows has other benefits not related to soldier fly, and bare fallows are inadvisable in many areas during the wet season.

A range of extension activities (articles, shed meetings, large formal meetings) have been undertaken during the project, promoting soldier fly management and particularly fallowing methods that involve either sprayout of old ratoons or rotation with soybeans, while avoiding the severe cultivation that has been recommended in the past. Work is continuing with farmers in groups formed within BSS225.

4.0 OTHER ISSUES

4.1 Likely impact on the sugar industry

Soldier flies continue to be a serious problem for the sugar industry, and their impact is underestimated. The usual procedure of estimating visible losses in severely affected fields takes no account of costs due to shortening of crop cycles and more frequent planting costs and fallowing with missed harvests. A recent situation statement for Bundaberg (Linedale unpubl.) estimates the true annual cost of soldier fly to the district (Bingera, Fairymead, Millaquin) at $1.7m, far higher than the conventional estimate for, say, 1997 of $0.2m. Reported losses across all Queensland districts for that year totalled $1.0m, estimated conventionally (Proc. CPPB Conference, Ballina). If the underestimation factor from Bundaberg is applied to this figure, losses to the Queensland industry would have amounted to $7.7m.

There is no quick solution on the horizon for soldier fly (eg no insecticide). Suitable farm management techniques as developed in this project are the only way of reducing losses caused by the pest.

4.2 Project technology

No commercially significant developments have arisen from this project.

4.3 Recommendations for related R, D & E

1. Investigate the role of ants in canefields, in relation to the population dynamics of soldier fly and other pests.

2. Determine the cause of disappearance of eggs and small larvae between soldier fly generations.

3. Test some of the possible relationships between soil nutrients and elements and soldier fly numbers, as suggested by this project and a population dynamics study currently under way at Mackay.

4. Develop and extend suitable techniques for managing fields with a trash blanket in Bingera and some other southern districts; this may or may not affect soldier fly status, but there is a grower perception that trash blanketing is not viable on some farms, especially where soldier fly are present.

5. Determine whether early crop destruction combined with early planting constitutes an effective fallow for soldier fly management, to avoid the loss of plant crop yield that accompanies late planting.

6. Develop management plans for affected farms, with a proactive rather than reactive approach to farm management for soldier fly. In particular, a decision before the harvest season on which fields to take out would allow those fields to be cut and the crops destroyed early. This would improve the efficacy of fallowing, and may even allow those fields to be planted early the following year (see 5. above).

7. Carry out extensive snapshot surveys to establish why soldier flies are prevalent in some areas (particularly certain farms in Bingera, Fairymead and Maryborough) and are at low levels on other farms (especially in Millaquin and Isis) where they have formerly been a problem.

8. Carry out longer term studies (more than one crop cycle) on relationships between farm management methods, and especially trash blanketing, and both soil fauna and soldier flies.

9. For general soldier fly research, adult biology and the mechanism of the effect of larvae on sugarcane ratooning are topics that warrant more work.

10. Differences in resistance/tolerance between new varieties should be measured in field trials (see report BS61S), as part of an IPM system.

4.4 Publications

Samson, P.R. and Phillips, L.M. (1997). Farming practices to manage populations of sugarcane soldier fly, *Inopus rubriceps* (Macquart), in sugarcane. *Soil Invertebrates in 1997* (eds. Allsopp, P.G., Rogers, D.J. and Robertson, L.N.), pp. 96-101. BSES, Brisbane.

A large publication is planned covering the long-term trials in the project.

5.0 LARGE-PLOT TRIALS OF FARMING PRACTICES

5.1 Introduction

The sugarcane soldier fly *Inopus rubriceps* Macquart (Diptera: Stratiomyidae) is native to Australia (Robertson 1985). Larvae feed on the sugarcane roots, causing poor growth and weak regrowth (ratooning) from stubble after harvest. Most individuals develop from egg to adult in one year in Queensland and emerge as adults in autumn (Robertson 1987). The pest can pass through several generations during a cropping cycle of sugarcane that usually occupies at least four years. Soldier fly damage to sugarcane crops is more frequently seen several years after planting (Samson *et al*. 1991).

Sugarcane soldier flies naturally inhabit grasslands in Australia (Robertson 1985). A range of polyphagous beetle (Coleoptera) predators attacks the immature stages in both grasslands and sugarcane fields, and three species of wasp (Hymenoptera: Diapriidae) parasitise pupae (Robertson and Zalucki 1985). Robertson (1987) measured higher densities of soldier fly larvae in sugarcane fields than in grasslands. He suggested that cultivation before planting and organochlorine residues may cause low densities of soldier fly and its natural enemies soon after planting of sugarcane, with regular crop replacement preventing the stability that was reached in grasslands.

Farming practices may influence soldier fly populations in sugarcane crops directly, or indirectly by affecting numbers of natural enemies. Meetings with growers were held in 1995 and a range of management options was discussed with the aim of managing soldier fly populations. This list was narrowed down to six that were of high priority. This section of the report describes the rationale and implementation of these experimental practices, and presents results up to the young third ratoon crop when several trials were ploughed in.

5.2 Materials and methods

5.2.1 Farming practices investigated

Monitoring of canefields was started in the last year of a cropping cycle of sugarcane, just before the old crop was destroyed. Different cultural treatments were then imposed at crop destruction (‘ploughout’), during the subsequent fallow, or at planting and during growth of the new crop planted back into the field.

I investigated two different combinations of times of destruction of the old crop and planting of the new crop:

1) Short fallow, ie late crop destruction (November-December) combined with early planting (March of the following year). This is standard practice in many areas in southern Queensland; it provides little break from cane.

2) Long fallow, ie early crop destruction (usually September-October) combined with late planting (August-September of the following year). This destroys the larval food source (old crop) when larvae are still small, it provides a long break from cane to starve larvae, and ensures that no cane is present during the autumn flight period to attract ovipositing females.

Table 1: Treatments being evaluated in trials, and reasons for their inclusion

Treatment	Aim
Short fallow - early plant	
Standard	Baseline to evaluate other treatments.
Mill mud	Organic matter to encourage decomposers, which provide alternative food for generalist predators that also feed on soldier fly.
Green-cane trash blanket after first harvest [a]	1) Encourage decomposers and thus predators which also eat soldier flies. 2) Provide a suitable habitat for predators.
Long fallow - late plant	
Bare fallow	Kill soldier fly by starvation and cultivation; traditional control method, but may be hard on natural enemies.
Soybean rotation	1) Initial fallow plus cultivation to kill some larvae. 2) Soybean crop over summer to protect soil and re-establish soil fauna; soybeans die before soldier fly flight period. 3) Minimum-tillage planting of cane into soybean stubble to preserve soil fauna.
Sprayout of old crop with old trash retained	1) Kill soldier fly by starvation - old trash blanket to suppress grasses which may be alternative hosts. 2) Preserve natural enemies into new crop by minimum-tillage planting.

[a] All other treatments had trash removed after each harvest.

The six treatments within these two fallow lengths, and their rationale, are listed in Table 1.

5.2.2 Implementation of treatments

Sites for long-term trials were identified during 1995, before harvest of the standing crop. The extent of soldier fly infestations in potential trial sites was surveyed by scraping surface soil at different points within each field and counting the number of pupal cases present. Eight sites were chosen as listed in Table 2, four west of Bundaberg - Atkinson, Bengtson, Giles and Larsen, two near Maryborough - Downman and Doyle, and two near Mackay. The soil textures at each site in southern Queensland are given in Table 4.

Treatments were implemented in each of six unreplicated plots in each field. Plots were large, about 25 rows wide by 50 m long, to minimise insect movement between plots. They were arranged in two columns of three, with the early- and late-plant treatments side-by-side for ease of management (eg Figure 1).

Unfortunately, fallow plots at Hansen’s farm at Mackay were ploughed by the grower in May 1996. These included two treatments to be planted with minimum tillage. It was decided that this so compromised the trial that it was not worth continuing further. Alternative trial sites were investigated at Mackay during the 1996 harvest but a suitable replacement was not found.

Table 2: Dates of crop destruction and planting of new crop

Farm	Short fallow - early plant		Long fallow - late plant		
	Cultivate out	Plant	Cultivate out	Spray out	Plant
Atkinson	15/12/95	5/3/96	22/9/95	25/10/95	4/9/96
Bengtson	6/12/95	5/3/96	6/12/95	1/12/95	6/9/96
Downman	6/11/95	27/3/96	13/9/95	19/10/95	12/9/96
Doyle	6/11/95	27/3/96	18/9/95	19/10/95	13/9/96
Giles	10/12/95	19/3/96	15/9/95	25/10/95	28/8/96
Larsen	2/11/95	5/3/96	5/9/95	25/10/95	29/8/96
Craig	15/12/95	30/4/96	15/12/95	6/12/95	19/8/96
Hansen	4/12/95	24/4/96	4/12/95	29/11/95	-

Dates of stool destruction and of planting are given in Table 2. At three of the farms, the old crop in the long fallow plots was destroyed no earlier than cane in the short fallow plots, but all long fallow plots were planted late. The method of crop destruction by cultivation varied between farms but was typically by offset discs or by rotary hoe, and additional workings were carried out during the fallow. Most of the bare long fallow plots were ploughed during autumn in an attempt to bury soldier fly pupae, as was then recommended for soldier fly control (Allsopp and Bull 1987). Cultivation details are given in Table 3. Soybean plots were cultivated similarly to the bare fallow plots until the soybean seed was incorporated by shallow discing in December 1995, but were not cultivated again until sugarcane was planted. Soybean seed (Warrigal or Manark) was spread by hand at 70 kg/ha and Dual (metolachlor) applied at 3 L/ha for weed control.

Destruction of old stools by spraying with glyphosate was usually carried out later than destruction by cultivation (Table 2), as crops could not be sprayed until sufficient leaf area was present to intercept the herbicide. The trash from the old cane crop following green-cane harvest was retained on this plot to assist with weed control. Additional herbicide applications were needed during the fallow, but the plots received no cultivation until planting.

Table 3: Cultivation operations during the fallow period for all treatments except sprayout (excludes cultivation associated with the planter and subsequent weed control and filling-in of rows)

Farm	Regime	Number of operations during fallow				
		Rip	Disc [a]	Rotary hoe [a]	Plough	Total
Atkinson	Early plant	2	2	0	1	5
	Late bare	2	4	3	1	10
	Soybean [b]	1	3 + 1	2	0	6 + 1
Bengtson	Early plant	1	2	1	1	5
	Late bare	0	5	2	3	10
	Soybean [b]	0	2 + 1	1	0	3 + 1
Downman	Early plant	1	1	3	2	7
	Late bare	1	1	6	2	10
	Soybean [b]	1	0 + 1	3	0	4 + 1
Doyle	Early plant	1	0	3	1	5
	Late bare	1	0	5	0	6
	Soybean [b]	1	0 + 1	2	0	3 + 1
Giles	Early plant	2	1	2	1	6
	Late bare	2	5	1	1	9
	Soybean [b]	1	4 + 1	0	0	5 + 1
Larsen	Early plant	1	1	1	2	5
	Late bare	1	1	5	1	8
	Soybean [b]	1	0 + 1	3	0	4 + 1
Craig	Early plant	0	3	0	0	3
	Late bare	0	3	1	1	5
	Soybean [b]	0	2 + 1	0	0	2 + 1

[a] Disc includes grubber (coil leg plus harrows) or harrow; rotary hoe includes power harrow.
[b] Operations include a shallow discing to cover soybean seeds.

Planting in the early-plant plots was done by the farmers using conventional equipment. In the six southern trials, the late-plant plots used a modified planter with narrow planting boards to cause minimal soil disturbance. A pair of reversed discs was mounted behind the planter to produce a hill over the cane. A single central ripper tine preceded by two coulter discs spaced 310 mm apart and followed by two reversed discs was run along the old planting rows in the sprayout plots and continued into soybean and bare fallow just before late planting, to loosen the soil. In the Mackay trial at Craig, rows for late planting were marked out with two passes of a trash incorporator, and cane was then planted with narrow planting boards.

Varieties planted were Q151 in the four trials near Bundaberg and Q124 in the remaining trials near Maryborough and Mackay. Q151 was chosen for planting near Bundaberg because it was thought to be tolerant of soldier fly, but Q124 was used in other districts because it was the predominant or increasing variety at that time.

Mill mud was applied to one early-plant plot in each trial during the fallow, at rates from 95-222 t/ha. Additional applications were made in subsequent ratoon crops. Trash was retained on one plot in each trial from the 1997 plant crop harvest onwards. The whole of each trial was harvested green and trash burned or raked from all except this plot.

Table 4: Texture of soils at each of the trial sites in southern Queensland

Farm	Sand%	Silt%	Clay%
Atkinson	25	28	47
Bengtson	45	20	35
Downman	45	31	24
Doyle	53	22	25
Giles	33	23	44
Larsen	27	24	49

5.2.3 Sampling and analysis

The sampling area was confined to a central 6-row by 15 m area in each plot, with the surrounding area acting as a buffer.

Soil samples were taken during the fallow period for determination of organochlorine residues. Samples were combined for the whole of each trial and sent to BSES Indooroopilly for analysis.

Samples for soldier fly and other fauna comprised four soil cores, 65 mm diameter and 200 mm deep, taken beside each of 10 cane stools in each plot. Samples were wet-sieved through a 1 mm mesh screen, and soldier fly larvae and other fauna were sorted from roots and debris in water under magnification. Soldier fly larvae were grouped into weight classes, and numbers corrected for inefficient recovery estimated to range from 14% for the smallest class (<0.16 mg) to 100% for larvae >15 mg and pupae. Density was calculated within the row only; the interrow space contains few larvae (Robertson 1984a; Samson and McLennan 1992b). Each trial was sampled once during the period from August-November 1995, before the old crop was destroyed, and then again in February-March 1997 after the new crop had established in both early- and late-plant plots. Sampling then continued annually with the final sample taken early in the third ratoon of most trials.

Additional samples were collected during the fallow period at two farms, Atkinson and Downman, in March-April 1996 to assess the disappearance of larvae since crop destruction.

Four of the study sites were also sampled several times during the year early 1999-early 2000, to prepare a population budget within one generation. Samples were collected at strategic times to measure the density of large larvae in late summer, pupal cases in winter after the emergence of adults, small larvae in spring and large larvae again in summer. Only standard and trash treatments were sampled. The number of adults was estimated as the number of normal pupal cases, which persist near the soil surface for several months after adult emergence (Robertson 1984b).

Samples for measurement of the levels of *Metarhizium anisopliae* comprised 10 samples collected from beside cane stools and combined, from each plot. First samples were taken by spade in January 1997, in the new crop. Subsequent samples were collected with a 50 mm diameter auger to 200 mm depth in January-February 1998 and February-May 1999. On the latter two occasions, additional samples were taken from the centre of the interrows in the sprayout and bare fallow plots. The concentration of spores was determined by Dr Richard Milner, CSIRO Entomology, by suspending a subsample of soil in Tween 80 with sonication, diluting the suspension and plating it onto Veen's medium, and counting colonies.

Pitfall traps were placed in fields during late summer-autumn of 1999, in the second ratoon. Each trap consisted of a plastic cup of 11 cm diameter buried flush with the soil surface and containing water plus ethanediol (9:1) with a small volume of detergent added. Three traps were placed in each plot, just outside the central sampling area. Trapping periods were: Atkinson, 15/2/99-27/4/99; Bengtson, 19/2/99-16/4/99; Downman, 18/2/99-16/4/99; Doyle, 19/3/99-16/4/99; Giles, 17/2/99-15/4/99; Larsen, 16/2/99-16/4/99. Traps were emptied at intervals of 1-3 weeks and the contents sorted.

Crop yields were measured annually for the central six rows of each plot for the whole plot length. Weights in each row were measured by BSES weighing machine after cutting by a commercial harvester. Commercial cane sugar (ccs) was measured in two six-stalk samples from each plot, collected from the central six rows.

Soil samples were collected at the end of the study in June 2000 for measurement of nutrient levels. Ten auger samples (50 mm to 250 mm depth) were collected from each plot in the rows, combined and subsampled and sent to BSES Indooroopilly for analysis.

Numbers of soldier fly and soil fauna in core samples and pitfall traps, concentrations of *Metarhizium* spores, soil nutrient levels and crop yields were compared between treatments or farms by the least-significant-difference test when analysis of variance indicated a significant effect ($P = 0.05$), and the significance of contrasts between combinations of means was tested by *t*-test. Counts were transformed as $\log(x+1)$ before analysis. Mortality of soldier fly in each generation, K_{total}, was calculated assuming egg production of 285/female (Robertson 1984b) and a sex ratio of 1:1; thus a value of K_{total} of 2.154 indicates a stable population density. Possible relationships between K_{total} or soldier fly density and densities of other faunal groups or nutrient levels were tested by Spearman's rank correlation, using data from individual plots or from plots combined within farms. Population budgets for a single generation in trash and standard treatments were constructed as described by Robertson (1987), using the same terminology for *k*-values at different stages in the life cycle. Key factors in population change were examined by regression of *k*-values on K_{total}. All analyses were carried out using *Statistix for Windows* Version 1.0 (Analytical Software).

5.3 Results and discussion

5.3.1 Organochlorine residues

Organochlorine insecticides once used commonly used in canefields were BHC and dieldrin, primarily targeting canegrubs and soldier flies, respectively. Neither chemical is in current use. Levels of BHC were low at the trial sites, the highest being at Doyle (0.03 mg kg^{-1} beta isomer). However, appreciable residues of dieldrin were present at two sites, Giles (0.6 mg kg^{-1}) and Doyle (1.1 mg kg^{-1}). These levels compare with the residue of 2.1 mg kg^{-1} expected immediately after a single application of dieldrin at the formerly recommended rate of 6.7 kg ai ha^{-1} (Stickley and Hitchcock 1972). Dieldrin levels similar to those at Doyle have led to a decrease in potential predators and an increase in numbers of soldier fly in experimental plots (Robertson 1984b; Robertson and Zalucki 1984).

5.3.2 Soldier fly populations and crop yields at each farm

5.3.2.1 Atkinson

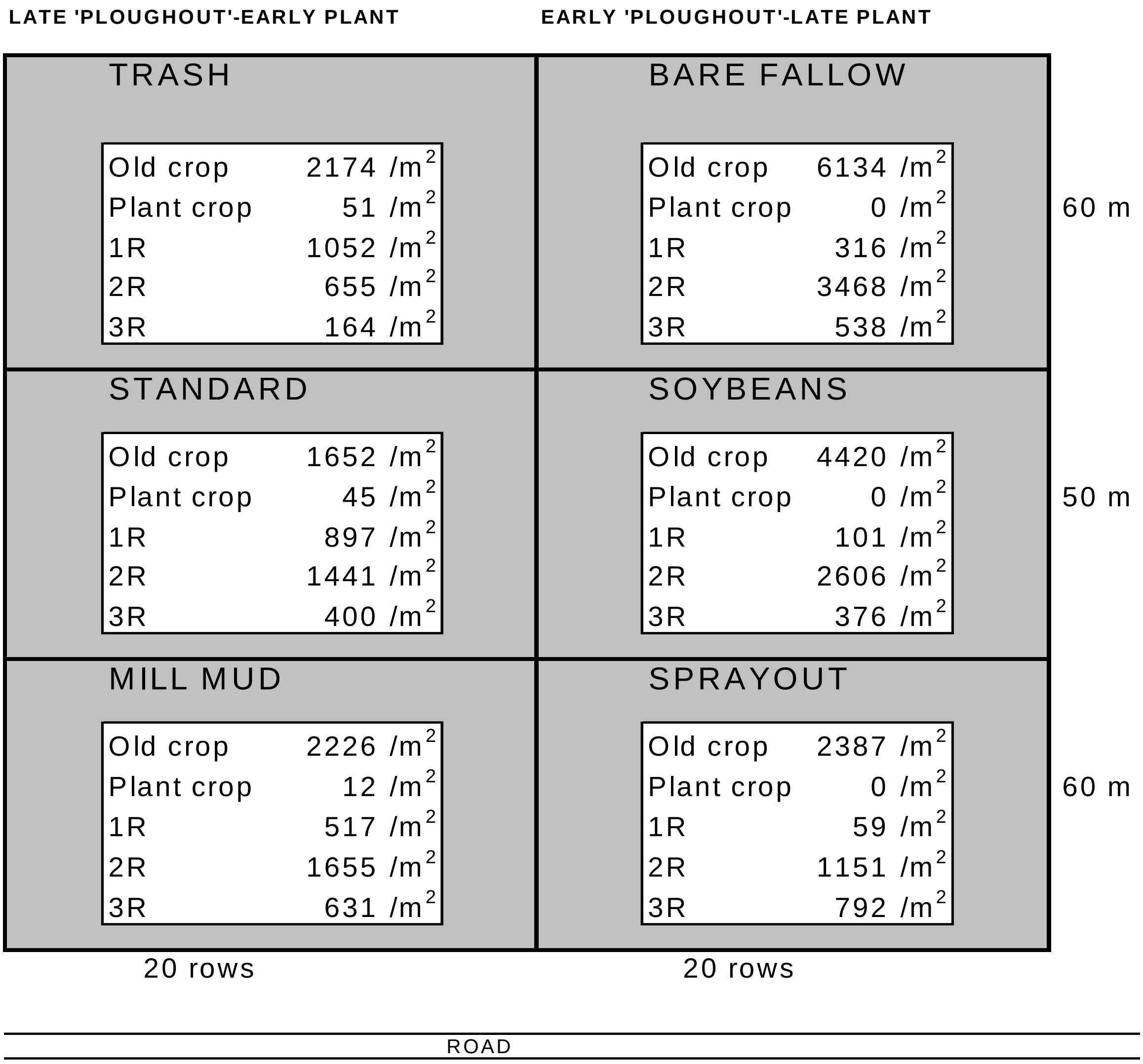

Figure 1: Numbers of soldier fly annually in the trial at Atkinson

Densities of soldier fly larvae in the old crop at Atkinson ranged from 1650 to 6130 m^{-2} (Figure 1). No larvae were found in the plant crop in any of the early ploughout-late plant (long fallow) plots, but some larvae were found in each of the early-plant plots. Densities then increased in successive years up to second ratoon, in most plots. In the trash plot, however, densities declined between the first and second ratoons. Numbers declined in all plots in the third ratoon.

Crop yields at Atkinson were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 5). In the first ratoon, the trash plot produced the highest yield after a dry year despite having the highest density of soldier fly larvae (Figure 1). Yields increased in all plots in the second ratoon with a return to better rainfall, despite high densities of soldier fly larvae in most plots. The best return over three harvests was produced from early-planted plots, and particularly from the trash plot. Of the late-plant treatments, both soybean and sprayout options for fallow management produced good yields, when compared with a bare fallow.

Levels of phosphorus in 2000 were low or marginal in several plots, trash (7 mg/kg), bare fallow (12 mg/kg) and sprayout (14 mg/kg).

Table 5: Yield and gross return of a crop cycle of a plant crop and two ratoons at Atkinson (Q151)

	Long fallow - late plant			**Short fallow - early plant**		
	Bare fallow	**Soybeans**	**Sprayout**	**Standard**	**Trash**	**Mill mud**
Plant crop (25/8/97)						
Cane (t/ha)	93	90	102	126	139	139
ccs	15.7	15.4	15.1	15.5	15.9	15.1
Sugar (t/ha)	14.6	13.8	15.4	19.6	22.0	21.0
Return ($/ha)[a]	2766	2596	2848	3690	4207	3890
First ratoon (20/8/98)						
Cane (t/ha)	66	68	76	61	81	69
ccs	15.3	15.1	14.1	15.1	15.1	14.8
Sugar (t/ha)	10.2	10.3	10.8	9.2	12.2	10.2
Return ($/ha)[a]	1899	1905	1912	1697	2264	1862
Second ratoon (21/11/99)						
Cane (t/ha)	78	96	96	94	96	94
ccs	14.9	15.3	15.8	15.3	15.1	14.9
Sugar (t/ha)	11.6	14.7	15.1	14.3	14.5	14.1
Return ($/ha)[a]	2141	2750	2872	2680	2679	2585
Sum, plant crop-second ratoon						
Cane (t/ha)	237	254	274	281	315	302
ccs	15.3	15.3	15.0	15.3	15.4	14.9
Sugar (t/ha)	36.4	38.8	41.2	43.1	48.7	45.2
Return ($/ha)[a]	6806	7250	7632	8067	9151	8337

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 6: Fertilising and cultural operations at Atkinson

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	188 [a]	DAP, GF501	190, 125	-	-
1R	114	GF501	750	Coulter	Yes
2R	139	GF506	750	Coulter	Yes

[a] Pre-plant.

5.3.2.2 Bengtson

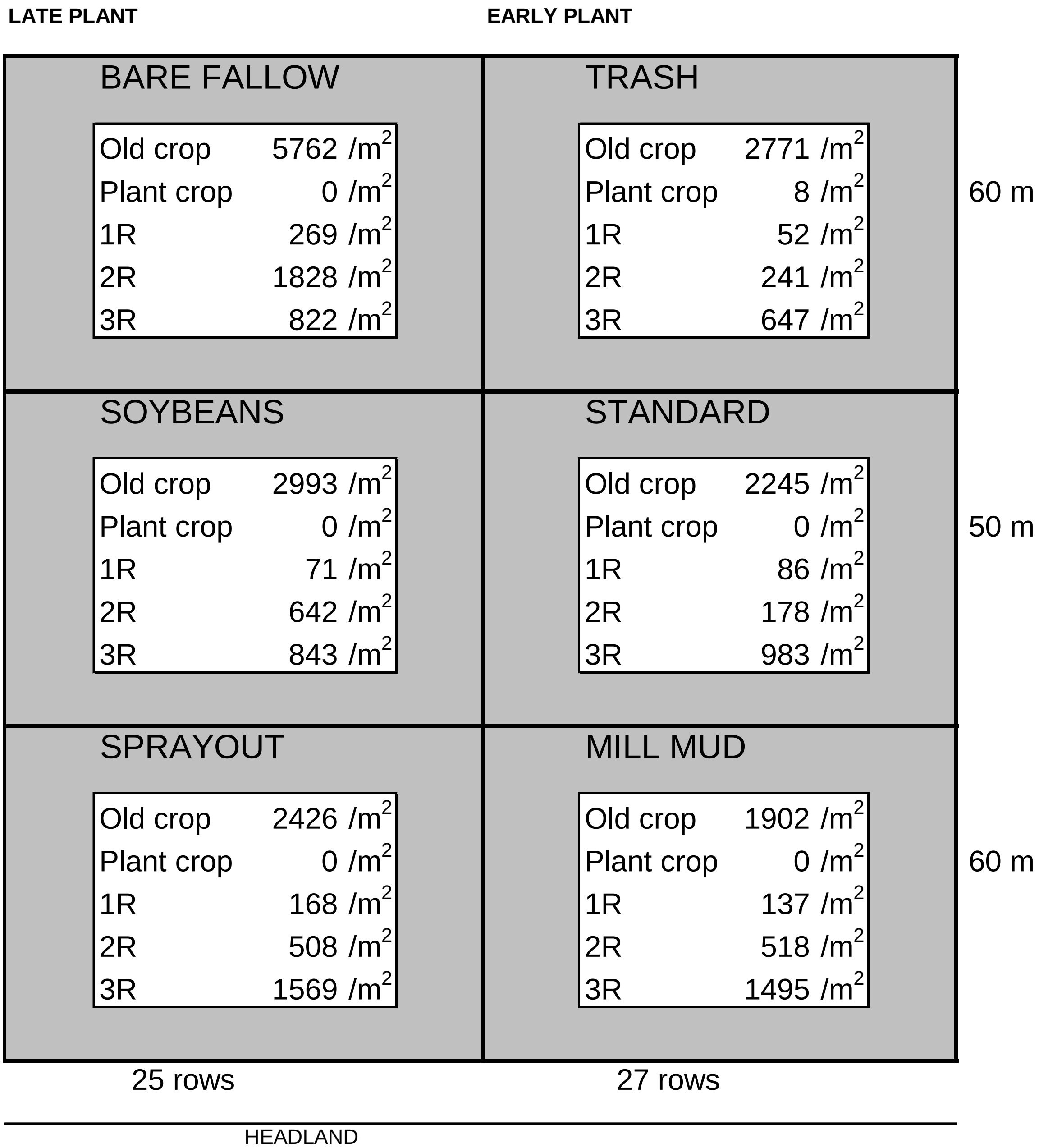

Figure 2. Numbers of soldier fly annually in the trial at Bengtson

Densities of soldier fly larvae in the old crop at Bengtson ranged from 1900 to 5760 m^{-2} (Figure 2). No larvae were found in the plant crop in any of the late-plant plots, or in two of the three early-plant plots. Densities then generally increased in successive years up to third ratoon, although a high density was measured in the bare fallow plot in the second ratoon.

Crop yields at Bengtson were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 7). Yields in the first ratoon seemed to decline down the length of the field (ie bare fallow and trash > soybeans and standard > sprayout and mill mud), probably because the latter pots were at the bottom of the slope and the end of the water run in this flood-irrigated trial (Figure 2). Yields increased in all plots in the second ratoon with a return to better rainfall. Good yield of the bare fallow plot in the second ratoon did not reflect the high soldier fly density in this plot (Figure 2). Returns over three harvests appear to have been strongly influenced by the position of plots within the field, and do not indicate the true value of different management options.

Levels of phosphorus in 2000 were marginal (14-20 mg/kg) in all plots except the mill mud treatment (30 mg/kg).

Table 7: Yield and gross return of a crop cycle of a plant crop and two ratoons at Bengtson (Q151)

	Long fallow - late plant			**Short fallow - early plant**		
	Bare fallow	**Soybeans**	**Sprayout**	**Standard**	**Trash**	**Mill mud**
Plant crop (9/9/97)						
Cane (t/ha)	87	73	77	108	107	111
ccs	15.7	15.6	15.7	15.8	16.4	15.3
Sugar (t/ha)	13.6	11.4	12.1	17.1	17.5	17.0
Return ($/ha)[a]	2585	2151	2301	3261	3393	3174
First ratoon (29/7/98)						
Cane (t/ha)	70	60	35	39.8	57	38
ccs	14.4	13.3	13.1	13.2	14.4	12.1
Sugar (t/ha)	10.1	7.9	4.6	5.3	8.2	4.6
Return ($/ha)[a]	1809	1349	772	890	1478	725
Second ratoon (3/8/99)						
Cane (t/ha)	108	106	87	96	84	84
ccs	15.4	15.2	14.7	15.7	15.4	14.9
Sugar (t/ha)	16.6	16.2	12.8	15.1	12.9	12.6
Return ($/ha)[a]	3113	3008	2326	2856	2422	2312
Sum, plant crop-second ratoon						
Cane (t/ha)	264	239	199	244	247	233
ccs	15.2	14.7	14.5	14.9	15.4	14.1
Sugar (t/ha)	40.3	35.5	29.5	37.5	38.6	34.2
Return ($/ha)[a]	7508	6508	5399	7007	7294	6212

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 8: Fertilising and cultural operations at Bengtson

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	149 [a]	DAP, 150S	250, 625	-	-
1R	102	150S	750	Surface	Yes
2R	53 [b]	150S	750	Surface	Yes

[a] Pre-plant.
[b] Applied in interrows only.

5.3.2.3 Downman

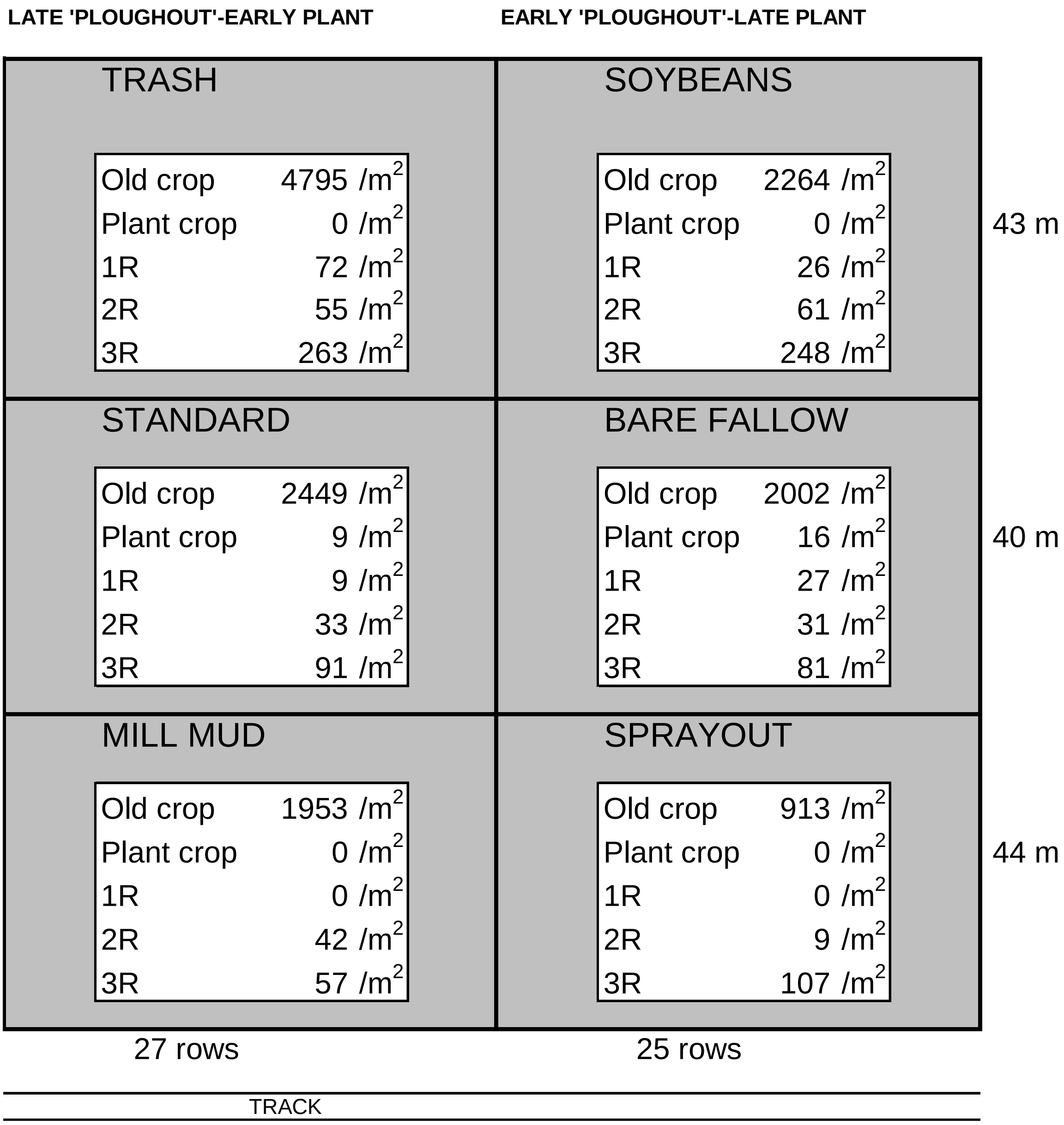

Figure 3: Numbers of soldier fly annually in the trial at Downman

Densities of soldier fly larvae in the old crop at Downman ranged from 910 to 4800 m^{-2} (Figure 3). Larvae were found in the plant crop in one late- and one early-plant plot. Densities then increased in successive years up to third ratoon, but only slowly; densities remained much lower than they had been in the previous crop in all plots.

Crop yields at Downman were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 9). Yields of the late-plant plots were down in the second ratoon, for unknown reasons not related to soldier fly, which were present in only low numbers (see Figure 3). The soybean plot yielded better than all other late-plant plots, and the mill mud plot yielded better than all other early-plant plots, over three harvests, although ccs of the latter treatment was relatively poor.

Levels of several nutrients were low or marginal in 2000; phosphorus <20 mg/kg in standard (13 mg/kg) and trash (17 mg/kg) plots, sulphur <7 mg/kg in sprayout (4 mg/kg), mill mud (5 mg/kg) and standard (6 mg/kg) plots, potassium (nitric) at 0.13-0.21 me% in all except mill mud (0.53 me%) plots, and available silicon <10 mg/kg in sprayout (6 mg/kg), bare fallow (8 mg/kg) and standard (8 mg/kg) plots.

Table 9: Yield and gross return of a crop cycle of a plant crop and two ratoons at Downman (Q124)

	Long fallow - late plant			**Short fallow - early plant**		
	Bare fallow	**Soybeans**	**Sprayout**	**Standard**	**Trash**	**Mill mud**
Plant crop (11/9/97)						
Cane (t/ha)	89	103	85	115	112	114
ccs	15.9	15.5	16.1	16.7	16.4	16.3
Sugar (t/ha)	14.2	16.0	13.7	19.2	18.3	18.7
Return ($/ha)[a]	2717	3007	2629	3766	3559	3610
First ratoon (31/10/98)						
Cane (t/ha)	106	116	106	86	110	118
ccs	15.2	15.8	15.6	14.6	15.8	13.6
Sugar (t/ha)	16.1	18.2	16.5	12.5	17.4	16.0
Return ($/ha)[a]	2993	3473	3118	2271	3306	2765
Second ratoon (30/10/99)						
Cane (t/ha)	68	77	60	82	85	101
ccs	15.9	16.2	16.2	16.7	16.2	15.6
Sugar (t/ha)	10.8	12.5	9.7	13.7	13.7	15.8
Return ($/ha)[a]	2057	2419	1868	2680	2642	2981
Sum, plant crop-second ratoon						
Cane (t/ha)	263	296	250	283	306	333
ccs	15.7	15.8	16.0	16.0	16.1	15.2
Sugar (t/ha)	41.1	46.8	39.9	45.4	49.4	50.4
Return ($/ha)[a]	7767	8899	7614	8717	9507	9356

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 10: Fertilising and cultural operations at Downman

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	211 [a]	CK66, urea	500, 100	-	-
1R	169	CK140	625	Coulter [b]	Yes [b]
2R	204	CK140	625	Coulter	No

[a] Pre-plant.
[b] Fertiliser was applied in centre of interrow using a coulter and ripper tine in all plots in 1R; beside stool in 2R.

5.3.2.4 Doyle

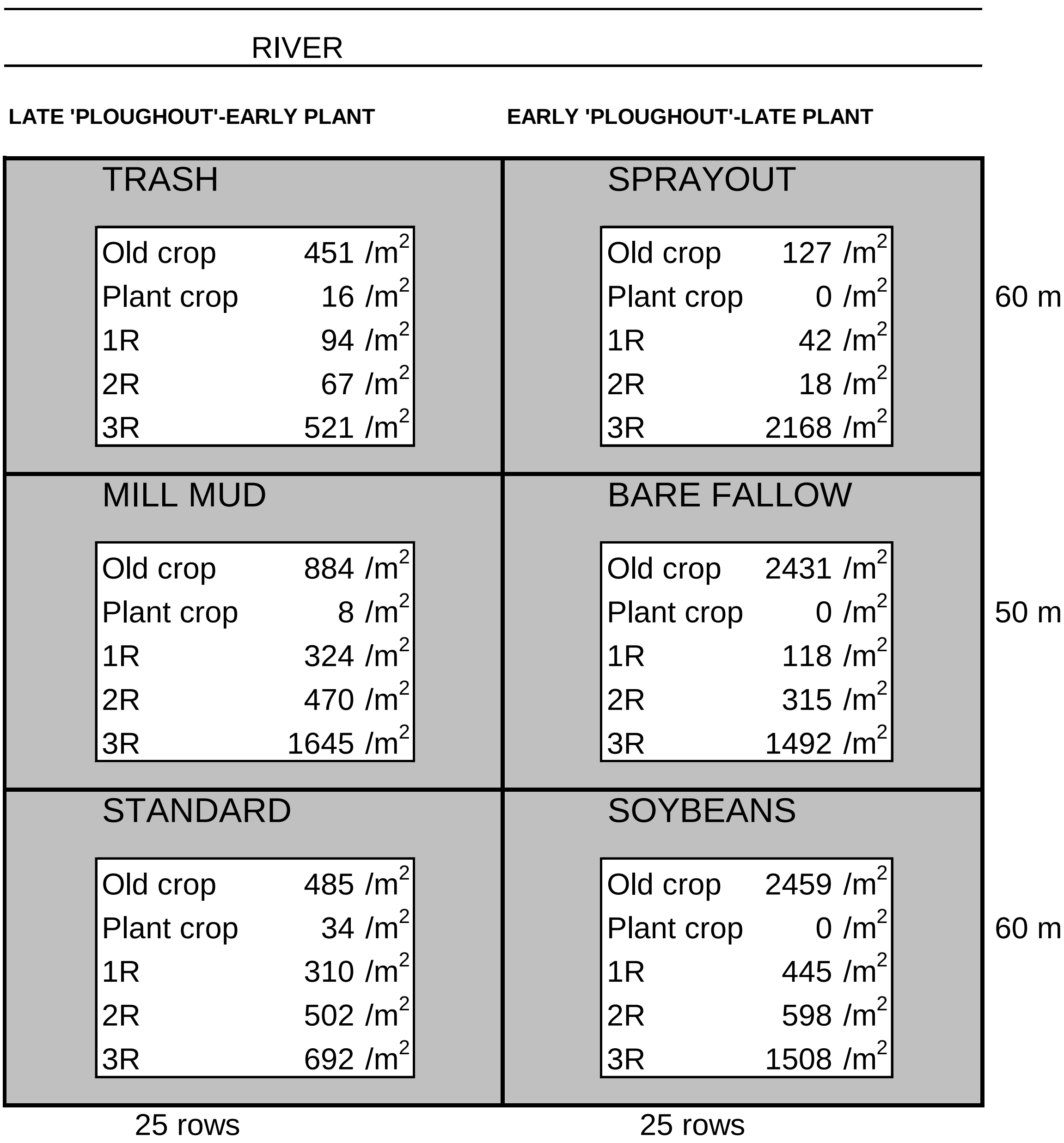

Figure 4: Numbers of soldier fly annually in the trial at Doyle

Densities of soldier fly larvae in the old crop at Doyle ranged from 130 to 2460 m^{-2}, with lowest numbers at the river end (Figure 4). No larvae were found in the plant crop in any of the early ploughout-late plant plots, but some larvae were found in each of the early-plant plots. Densities then increased in successive years up to third ratoon in all except the two plots closest to the river. These had been inundated by a rise in river level in February 1999, one month before the second ratoon sample was collected; densities fell at this sample but then increased greatly into the third ratoon.

Plant crop yields at Doyle were very high in all plots, particularly those planted early (Table 11). Yields could not be measured in the first ratoon, because of wet conditions. The trash plot produced the highest yield in the second ratoon, but this may not have been due to any effect of trash as most of the blanket had been washed away by flooding. This site was very heterogeneous in topography and soil type, and differences in yields between individual plots are probably not meaningful. Low yields for the plots distant from the river – bare fallow, soybeans, mill mud and standard – could have been influenced by moderate soldier fly populations in the second ratoon (see Figure 4), as Q124 is thought not to be very tolerant of soldier fly.

Table 11: Yield and gross return of a crop cycle of a plant crop and one ratoon at Doyle (Q124)

	Long fallow - late plant			Short fallow - early plant		
	Bare fallow	Soybeans	Sprayout	Standard	Trash	Mill mud
Plant crop (30/9/97)						
Cane (t/ha)	131	129	132	131	161	143
ccs	15.1	16.0	15.2	15.7	16.1	16.1
Sugar (t/ha)	19.7	20.6	20.1	20.6	25.9	23.1
Return ($/ha)[a]	3661	3941	3739	3905	4983	4441
First ratoon (14/12/98) – yields not measured						
Second ratoon (19/11/99)						
Cane (t/ha)	46	58	86	65	115	78
ccs	14.4	15.3	15.3	15.1	14.7	15.5
Sugar (t/ha)	6.6	8.9	13.2	9.8	16.9	12.1
Return ($/ha)[a]	1191	1663	2469	1817	3076	2278
Sum, plant crop and second ratoon only						
Cane (t/ha)	177	187	219	196	276	222
ccs	14.8	15.7	15.3	15.4	15.4	15.8
Sugar (t/ha)	26.4	29.5	33.3	30.4	42.8	35.2
Return ($/ha)[a]	4851	5605	6208	5722	8059	6719

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 12: Fertilising and cultural operations at Doyle

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	222 [a]	DAP, urea	280, 250	-	-
1R	170	CK150	690 [b]	Coulter [b]	Yes
2R	0	CK150	690	Surface	-

[a] Pre-plant.
[b] Rate in trash plot was 1870 kg/ha due to leak past auger.

5.3.2.5 Giles

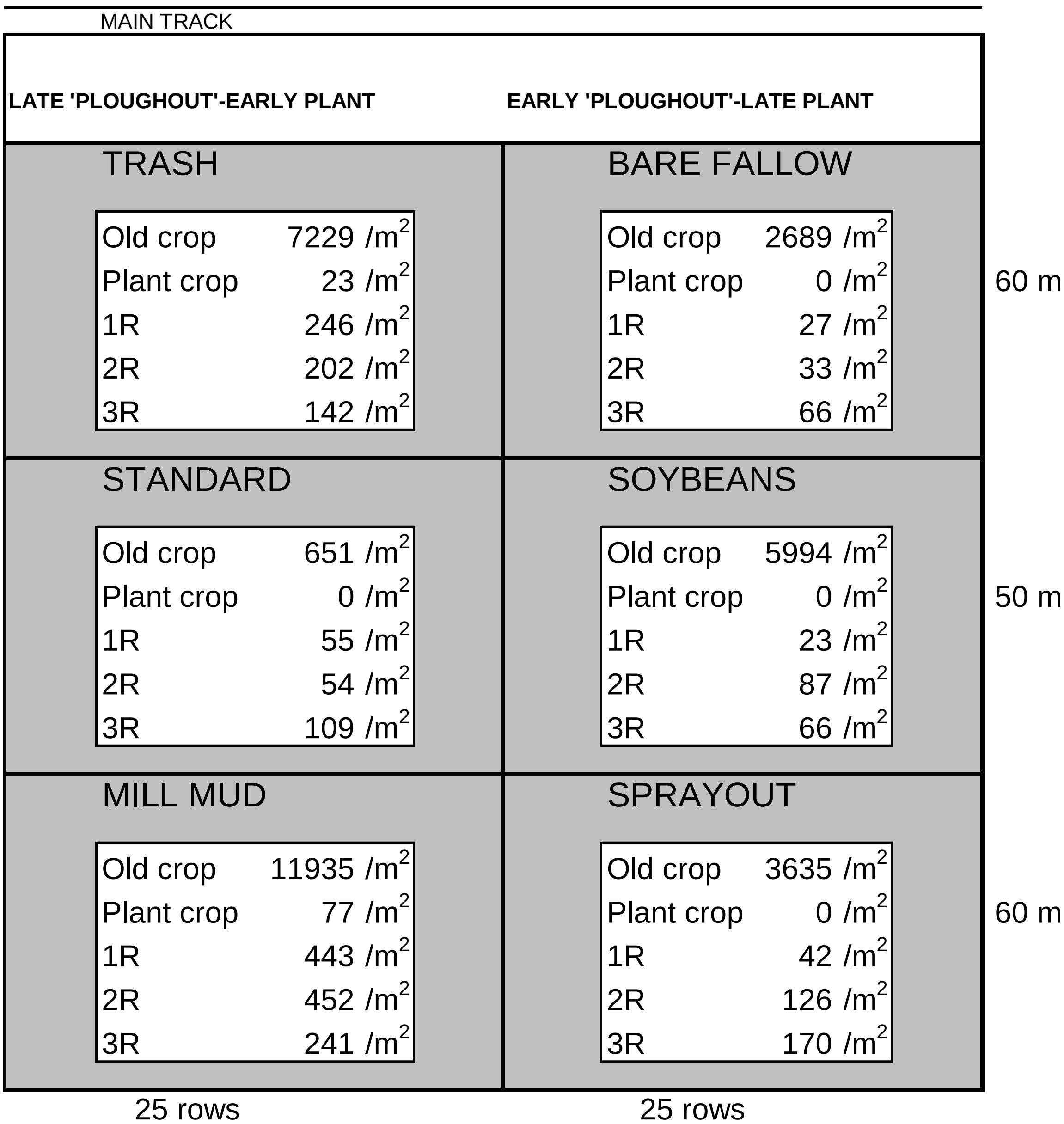

Figure 5: Numbers of soldier fly annually in the trial at Giles

Densities of soldier fly larvae were very high in the old crop at Giles, ranging from 650 to 11940 m^{-2} (Figure 5). No larvae were found in the plant crop in any of the early ploughout-late plant plots, but larvae were found in two of the early-plant plots. Densities then increased in the first ratoon but changed little thereafter, and until the third ratoon remained far below the densities in the old crop in all plots.

Crop yields at Giles were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 13). There was little difference between early-plant plots in the first ratoon; the 'trash' plot still had no trash at this time, as the harvesting contractor did not wish to harvest the plant crop green because of rocks in the field and the likelihood of damage to the basecutters. Two of the late-plant plots, bare fallow and sprayout, yielded well in the first ratoon. The first ratoon in the trash plot was cut green and trash retained, and this plot yielded poorly in the second ratoon. It may be noteworthy that fertiliser was placed on top of the trash rather than in the ground in this trial (Table 14), and there also seemed to be some compaction due to wheel travel in the rows in this plot. Over a crop cycle of plant and two ratoons, there was not a great difference between cane yields but the early-plant plots produced a greater return because of higher ccs in the high-yielding plant crop.

Levels of sulphur in 2000 were marginal at 5-7 mg/kg in every plot.

Table 13: Yield and gross return of a crop cycle of a plant crop and two ratoons at Giles (Q151)

	Long fallow – late plant			**Short fallow - early plant**		
	Bare fallow	**Soybeans**	**Sprayout**	**Standard**	**Trash (not in 1R)**	**Mill mud**
Plant crop (1/9/97)						
Cane (t/ha)	112	103	107	137	134	142
ccs	14.2	14.7	13.9	15.6	15.9	15.6
Sugar (t/ha)	15.9	15.1	14.9	21.4	21.3	22.2
Return ($/ha)[a]	2826	2762	2622	4051	4075	4190
First ratoon (31/7/98)						
Cane (t/ha)	101	90	101	82	(91)	86
ccs	14.0	14.2	14.2	13.7	(14.1)	14.1
Sugar (t/ha)	14.1	12.7	14.3	11.3	(12.9)	12.1
Return ($/ha)[a]	2490	2269	2558	1961	(2287)	2153
Second ratoon (4/8/99)						
Cane (t/ha)	117	110	110	108	83	105
ccs	15.4	15.4	15.2	15.5	15.6	15.1
Sugar (t/ha)	18.0	16.8	16.6	16.8	12.9	15.9
Return ($/ha)[a]	3387	3154	3085	3164	2434	2946
Sum, plant crop-second ratoon						
Cane (t/ha)	329	302	318	328	308	333
ccs	14.5	14.8	14.4	14.9	15.2	14.9
Sugar (t/ha)	48.0	44.7	45.9	49.5	47.1	50.2
Return ($/ha)[a]	8703	8184	8265	9176	8796	9289

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 14: Fertilising and cultural operations at Giles

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	152 [a]	CK44S, urea	375, 500	-	-
1R	122	GF552	625	No trash	-
2R	111	GF560	750	Surface [b]	Yes

[a] Pre-plant.
[b] Calam at 690 kg/ha.

5.3.2.6 Larsen

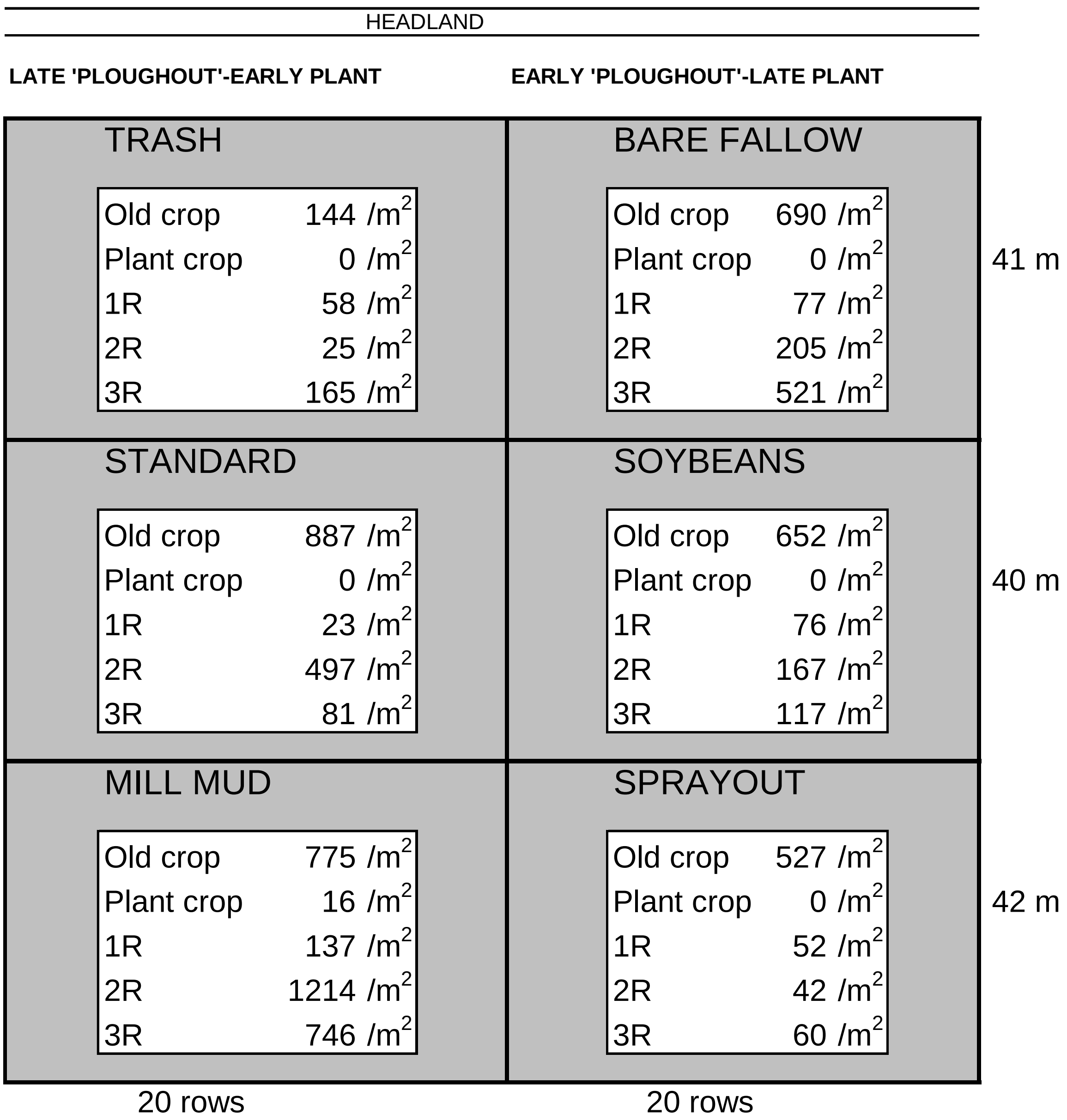

Figure 6: Numbers of soldier fly annually in the trial at Larsen

Densities of soldier fly larvae in the old crop at Larsen ranged from 140 to 890 m^{-2}, making this trial the least infested of the six southern trials (Figure 6). No larvae were found in the plant crop in any of the early ploughout-late plant plots, or in two of the early-plant plots. Densities then increased irregularly in successive years up to second or third ratoon, although they were always low in some plots (trash, soybeans, sprayout).

Crop yields at Larsen were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 15). The sprayout plot yielded poorly after the plant crop, and the cane seemed to struggle to ratoon. Planting was shallower than in other plots, because of minimal soil preparation, and the new roots may have been in dry soil after each harvest. Poor yields in the second ratoon did not seem related to soldier fly density, and the mill mud plot which had the highest soldier fly density also produced the greatest cane yield. The best return over three harvests was produced from early-planted plots, and particularly from the trash plot.

Levels of sulphur in 2000 were marginal at 4-5 mg/kg in every plot.

Table 15: Yield and gross return of a crop cycle of a plant crop and two ratoons at Larsen (Q151)

	Long fallow - late plant			**Short fallow - early plant**		
	Bare fallow	**Soybeans**	**Sprayout**	**Standard**	**Trash**	**Mill mud**
Plant crop (3/10/97)						
Cane (t/ha)	99	109	102	127	131	112
ccs	16.4	16.1	16.3	16.4	16.8	16.5
Sugar (t/ha)	16.2	17.6	16.6	20.8	22.0	18.5
Return ($/ha)[a]	3139	3389	3206	4042	4327	3613
First ratoon (20/10/98)						
Cane (t/ha)	93	98	73	93	100	87
ccs	16.0	15.9	15.9	15.7	16.4	15.9
Sugar (t/ha)	15.0	15.6	11.6	14.6	16.4	13.9
Return ($/ha)[a]	2866	2971	2208	2771	3189	2655
Second ratoon (17/8/99)						
Cane (t/ha)	74	67	56	74	70	76
ccs	15.2	15.1	14.7	15.2	15.2	14.5
Sugar (t/ha)	11.2	10.1	8.2	11.2	10.6	11.0
Return ($/ha)[a]	2082	1879	1498	2079	1977	1982
Sum, plant crop-second ratoon						
Cane (t/ha)	266	274	230	293	301	275
ccs	15.9	15.7	15.6	15.8	16.1	15.6
Sugar (t/ha)	42.3	43.3	36.3	46.6	49.0	43.4
Return ($/ha)[a]	8087	8239	6912	8893	9493	8250

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 16: Fertilising and cultural operations at Larsen

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	94 [a]	DAP, NitraK [b]	190, 312	-	-
1R	162	CK301S	690	Coulter	Yes
2R	198	CK300S	750	Surface	Yes

[a] Pre-plant.
[b] Mill mud plot only, Nitram 150 kg/ha instead of NitraK.

5.3.2.7 Craig

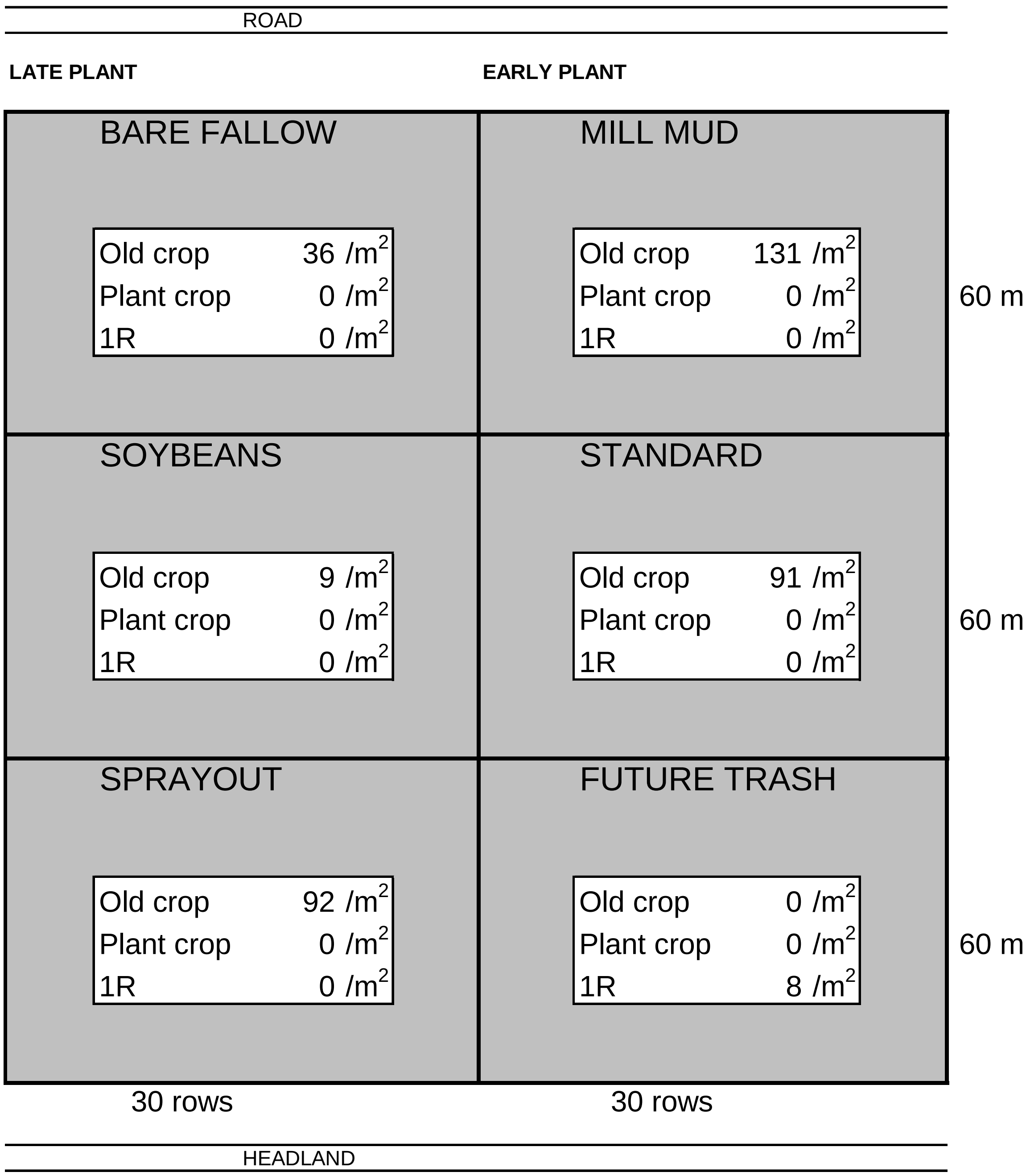

Figure 7: Numbers of soldier fly annually in the trial at Craig

Densities of soldier fly larvae in the old crop at Craig were low, with a maximum of 130 m^{-2}; no larvae were found in one plot (Figure 7). However, the old crop appeared damaged by soldier fly, and pupal cases were present in the preliminary survey. It is noteworthy that few normal (ie undamaged) pupal cases were found at this site (see later). Larvae were not found in any plots in the plant crop, and in only one plot at a very low density in the first ratoon. No further sampling was carried out after this time.

Crop yields at Craig were greater in all early-plant plots than in late-plant plots, in the plant crop (Table 17). Yields were not measured in ratoons.

Table 17: Yield and gross return of a plant crop at Craig

	Long fallow - late plant			Short fallow - early plant		
	Bare fallow	Soybeans	Sprayout	Standard	Future trash	Mill mud
Plant crop (7/10/97)						
Cane (t/ha)	74	80	81	107	90	109
ccs	17.0	17.6	17.1	17.4	17.7	17.1
Sugar (t/ha)	12.6	14.0	13.9	18.6	15.9	18.7
Return ($/ha)[a]	2488	2823	2749	3715	3205	3706
First ratoon – no harvest results						
Second ratoon – trial abandoned						

[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Table 18: Fertilising and cultural operations at Craig

Crop	Mill mud t/ha	Fertiliser			Trash centre-rip
		Type	kg/ha	Trash method	
P	?	160S	775	-	-
1R	162				
2R	198				

5.3.3 Analysis of soldier fly populations

5.3.3.1 Southern Queensland sites

Pupae and pupal cases collected from the old cane crop at each site were examined for signs of predation, parasitism or normal adult emergence. At least half of the cases from the six sites in southern Queensland appeared to have emerged normally (Table 19). Parasitised pupae or pupal cases were found at Atkinson and Bengtson. Six adults of the diapriid wasp *Neurogalesus carinatus* were reared from pupae at Atkinson.

Table 19: Fate of soldier fly pupae in the final ratoon of old crops at seven sites, as indicated by pupae and pupal cases recovered in a preliminary survey during site selection

Farm	No. of pupae and cases	% in each category			
		Normal	Eaten	Parasitised	Dead pupa
Atkinson	60	53	37	10	0
Bengtson	180	78	20	1	1
Downman	187	66	33	0	1
Doyle	8	50	50	0	0
Giles	51	67	33	0	0
Larsen	27	59	41	0	0
Craig	54	9	91	0	0

Densities of soldier fly larvae in the old sugarcane crop ranged from 612 m^{-2} at Larsen to 5356 m^{-2} at Giles (Figure 9a), with densities in individual plots as high as 11900 m^{-2} (Giles). Numbers of larvae in the new crop were expressed as a percentage of numbers present before the old crop was destroyed, to allow for initial differences between plots.

Table 20: Numbers of live soldier fly larvae and pupae during long fallow periods at two farms

	Bare fallow	Soybeans	Sprayout
Atkinson			
Live larvae in old crop, 11/9/95 (m^{-2})	6134	4420	2387
Live larvae in fallow, 19/3/96 (m^{-2})	0	71	86
Carryover from old crop (%)	0.0	1.6	3.6
Dead larvae in fallow (m^{-2})	38	15	45
Downman			
Live larvae in old crop, 4/9/95 (m^{-2})		2264	913
Live larvae/pupae in fallow, 30/4/96 (m^{-2})	not sampled	30	137
Carryover from old crop (%)		1.3	15.0
Dead larvae in fallow (m^{-2})		15	8

Long fallow treatments were sampled during the fallow at two farms, Atkinson and Downman, to assess the rate of disappearance of larvae. No live larvae were found at Atkinson in bare fallow plots in March but a small number were present in soybean and sprayout plots (Table 20). Some larvae and a small number of pupae were also found in these plots at Downman in April; bare fallow plots were not sampled. The recovery of more live larvae from the sprayout than from other plots is not surprising, as this was the only treatment where sampling was confined to the old rows, which had not been disturbed. The centre of the interrow of sprayout plots was sampled at Atkinson, and no larvae (live or dead) were found.

After fallowing, numbers of larvae in each plot in the new crop were less than 7% of those found before the old crop was destroyed, and no larvae were found in many plots. Where larvae were found, they were almost always in plots with a short fallow; 11 of the 18 early-plant plots compared with one of the 18 late-plant plots (Table 21). Overall, larval numbers in early-plant plots were 1.2% of the numbers in the old crop, in comparison with 0.05% where there had been a long fallow. Numbers of larvae in the new crop did not differ significantly between individual treatments ($P = 0.15$), but did differ significantly between the two fallow lengths ($P_{contrast} = 0.013$). The efficacy of long fallowing appeared to be independent of cultivation during the fallow, and larval numbers were greatly reduced even when cultivation was eliminated (Table 21, 'sprayout'). Estimated larval densities in the new crop were 16.6 and 0.9 m^{-2} after short and long fallows, respectively, over all trials.

In the first ratoon, the average number of larvae in the three treatments with a long fallow, 6.5% of the number in the old crop, was significantly lower than the number in the three short fallow treatments, 19.9% (Table 21, $P_{contrast} = 0.008$). There was no difference between treatments within each of the two fallow lengths ($P = 0.12$).

In the second ratoon, numbers of larvae did not differ significantly between individual treatments or between the two fallow lengths (Table 21, $P > 0.05$). Numbers generally appeared lower in the three treatments planted late than in the early-plant treatments, excepting the trash plots where numbers were surprisingly low. This stimulated a more detailed investigation of the change in soldier fly densities in the trash and standard treatments between the second and third ratoons, as described later.

By the third ratoon, there was no significant difference in soldier fly numbers between individual treatments or fallow lengths (Table 21, $P > 0.05$). Very large numbers of larvae in the sprayout treatment at Doyle, following flooding the previous February, inflated the average value for this treatment. It is possible that flooding precipitated an increase in soldier fly by inhibiting natural enemies, as postulated by Robertson (1984b). Omitting Doyle from the analysis, there was still no significant difference between individual treatments ($P = 0.58$) or between fallow lengths ($P_{contrast} = 0.26$). There was no indication that numbers of larvae were lower in the trash plot in the third ratoon, unlike the second.

Table 21: Numbers of soldier fly larvae over a crop cycle of plant and three ratoon crops, as a percentage of numbers before destruction of the old crop, on six farms in southern Queensland

Crop year and farm	Long fallow – late plant			Short fallow – early plant			P^b
	Bare	Soybeans	Sprayout	Standard	Trash	Mill mud	
Plant							
Atkinson	0.0	0.0	0.0	2.7	2.3	0.6	
Bengtson	0.0	0.0	0.0	0.0	0.3	0.0	
Downman	0.8	0.0	0.0	0.4	0.0	0.0	
Doyle	0.0	0.0	0.0	7.0	3.6	0.9	
Giles	0.0	0.0	0.0	0.0	0.3	0.6	
Larsen	0.0	0.0	0.0	0.0	0.0	2.1	
Mean Plant	0.1	0.0	0.0	1.7	1.1	0.7	0.147
1R							
Atkinson	5.2	2.3	2.5	54.3	48.4	23.2	
Bengtson	4.7	2.4	6.9	3.8	1.9	7.2	
Downman	1.3	1.1	0.0	0.4	1.5	0.0	
Doyle	4.9	18.1	32.8	63.9	20.9	36.6	
Giles	1.0	0.4	1.2	8.5	3.4[a]	3.7	
Larsen	11.2	11.7	9.8	2.6	40.7	17.7	
Mean 1R	4.7	6.0	8.9	22.2	22.7	14.7	0.117
2R							
Atkinson	56.6	59.0	48.2	87.2	30.1	74.4	
Bengtson	31.7	21.4	21.0	7.9	8.7	27.3	
Downman	1.6	2.7	1.0	1.3	1.2	2.1	
Doyle	13.0	24.3	14.2	103.6	14.8	53.2	
Giles	1.2	1.5	3.5	8.3	2.8	3.8	
Larsen	29.8	25.6	7.9	56.0	17.6	156.7	
Mean 2R	22.3	22.4	16.0	44.1	12.5	52.9	0.061
3R							
Atkinson	8.8	8.5	33.2	24.2	7.5	28.3	
Bengtson	14.3	28.2	64.7	43.8	23.3	78.6	
Downman	4.0	11.0	11.7	3.7	5.5	2.9	
Doyle	61.4	61.3	1705.6	142.7	115.6	186.0	
Giles	2.4	1.1	4.7	16.7	2.0	2.0	
Larsen	75.5	18.0	11.4	9.1	115.2	96.3	
Mean 3R	27.7	21.3	305.2	40.1	44.9	65.7	0.434

[a] This plot did not have the correct trash treatment after the 1997 harvest and was not included in mean.

[b] For the contrast long fallow *vs* short fallow, values of P were 0.013, 0.008, 0.067 and 0.452 for Plant, 1R, 2R and 3R crops, respectively.

Annual changes in soldier fly numbers in each treatment are shown in Figure 8. Densities fell to low levels in the plant crop in the long fallow treatments, bare fallow, soybeans and sprayout; they were not found in the soybean and sprayout plots and so cannot be shown on the log scale (Figure 8a). Densities increased rapidly in all treatments into the first ratoon (Figure 8a) and values of K_{total} were low for the period P-1R (Figure 8b). Densities increased in most treatments into the second ratoon, but at a slower rate than in the previous year, and values of K_{total} were greater for the period 1R-2R than for P-1R. Mean density actually fell in the trash treatment with a value for K_{total} of 2.18. Densities increased more rapidly in the long fallow treatments than in the short fallow periods during the first two years after planting, as indicated by low values of K_{total} for P-1R and 1R-2R (Figure 8b). Densities appeared to stabilise by the third ratoon, with values of K_{total} of most treatments being greater for the period 2R-3R than for 1R-2R. However, densities increased in the trash plot with an apparent reduction in K_{total} compared with the previous year. The large increase in mean density in the sprayout treatment in the third ratoon and the low value of K_{total} for 2R-3R were strongly influenced by the unusually high larval density in this treatment at Doyle, possibly caused by flooding.

A similar analysis was carried out between farms (Figure 9). Densities fell greatly during the fallow period. However, densities increased rapidly in young ratoons, with low values of K_{total}. There appeared to be substantial differences in population dynamics between farms. Rates of increase were low at Downman and Giles until the second ratoon. The population density at Giles then remained low until the third ratoon, a surprising result given that this site had the highest density of larvae in the old crop. There was a substantial increase in density at Downman in the last year, but the final density was still lower than at most other sites. Declining population densities were measured at Larsen and particularly Atkinson in the last year of sampling. Fluctuating densities and values of K_{total} at Doyle may have been due to flooding just prior to sampling in the second ratoon.

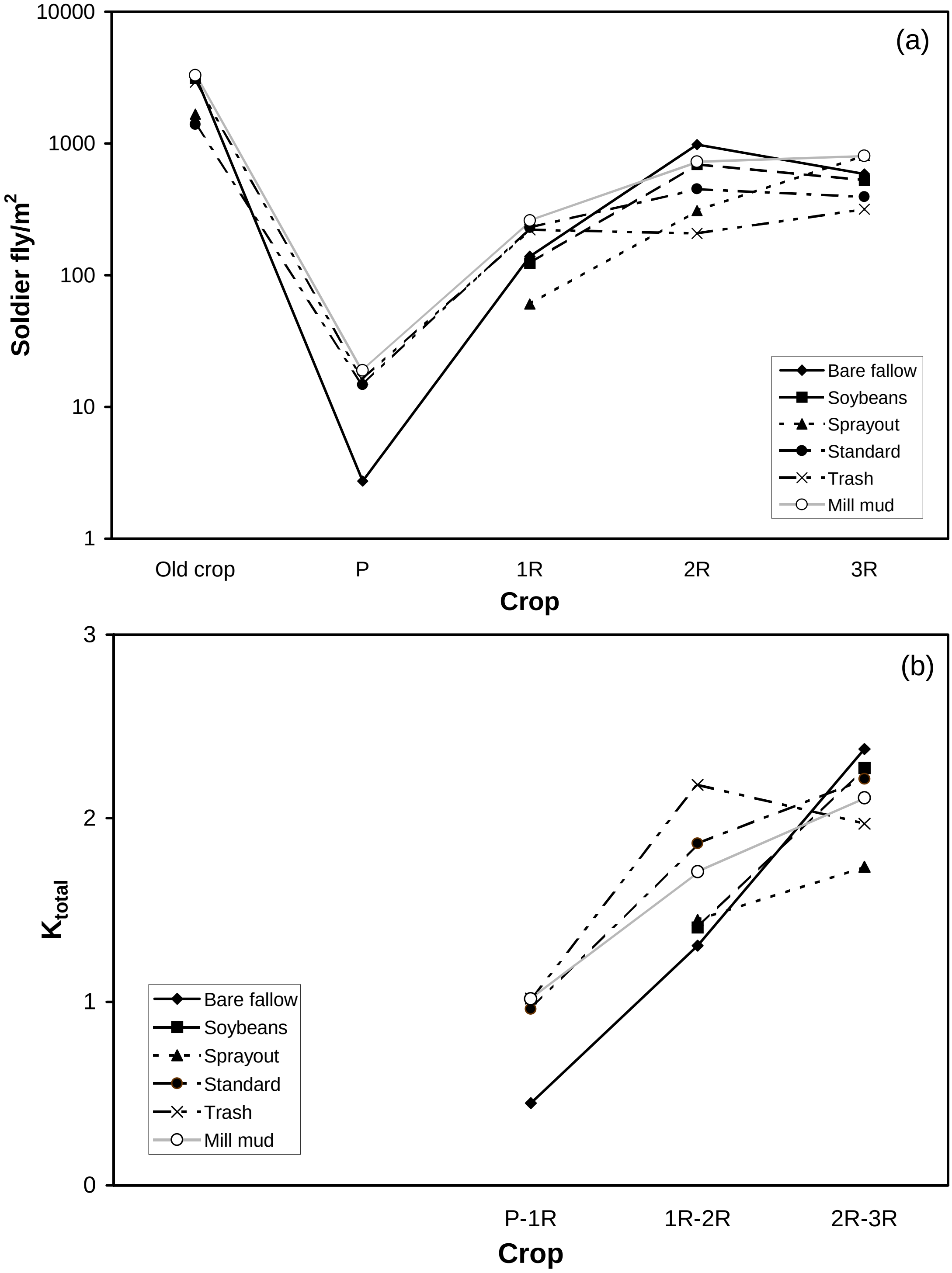

Figure 8: Annual changes in populations of soldier fly larvae in different treatments in trials in southern Queensland, (a) population density, and (b) generation mortality.

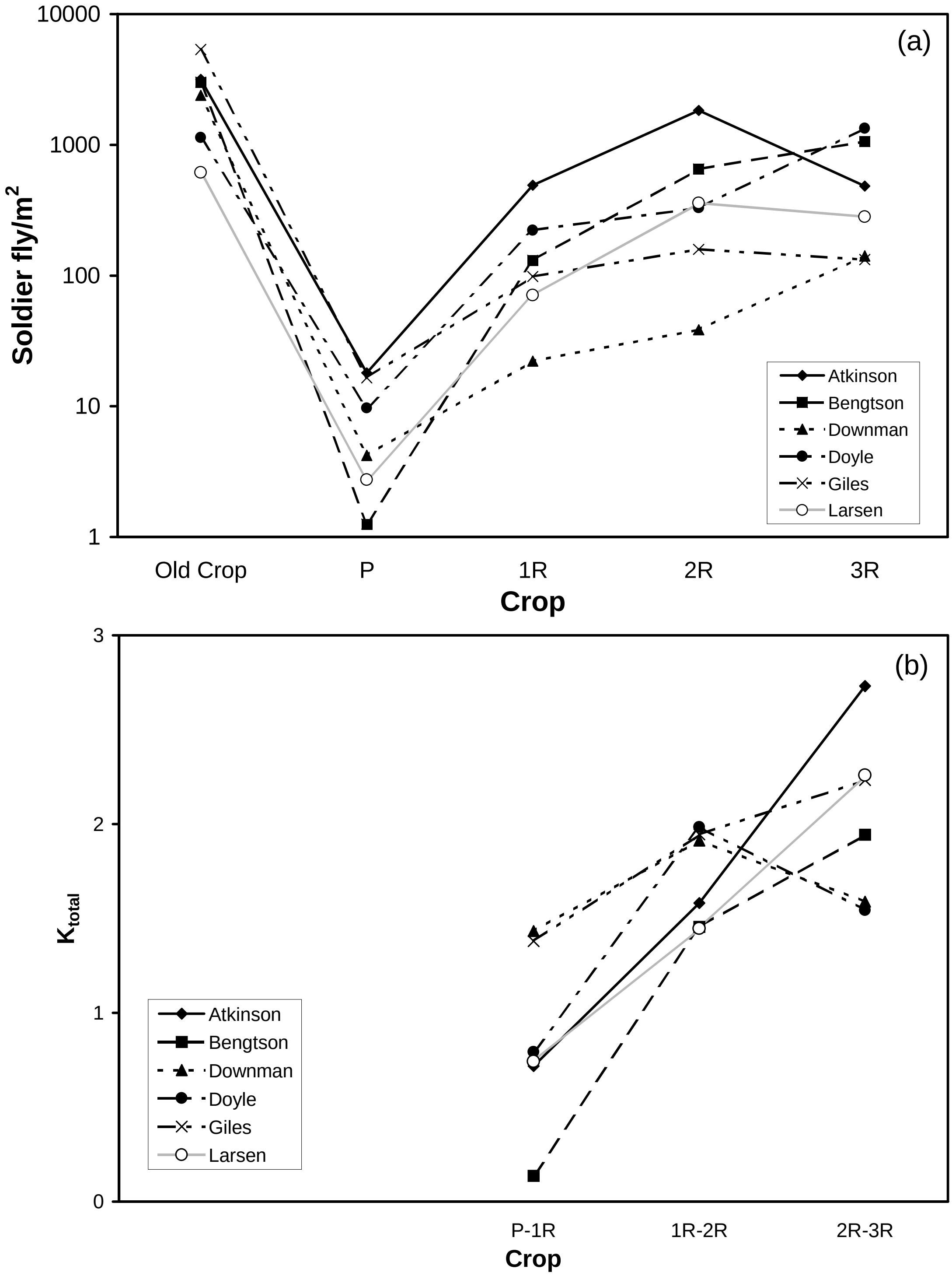

Figure 9: Annual changes in populations of soldier fly larvae on different farms in trials in southern Queensland, (a) population density, and (b) generation mortality.

A population budget was constructed for within-generation mortality between the times of sampling large larvae in the second and third ratoons, on four farms. Trash and standard treatments were compared, as they had shown differing rates of increase in the previous generation, between the first and the second ratoon.

Table 22: Population budget for one soldier fly generation from large larvae early in 1999 to large larvae in late 1999/early 2000, ie from second to third ratoon, for two different trash treatments at four farms.

Treatment and farm	K_{total}	k_3	k_4	k_5	k_{0+1}	k_2
Standard						
Atkinson	2.71	0.04	0.04	1.08	1.80	-0.11
Downman	1.57	0.00	0.00	0.20	1.52	-0.15
Giles	1.85	0.08	0.00	0.18	2.08	-0.48
Larsen	2.94	0.06	0.00	0.91	1.08	0.93
Mean	2.27	0.05	0.01	0.59	1.62	0.05
Trash						
Atkinson	2.76	0.03	0.01	1.20	2.00	-0.38
Downman[a]	1.48	0.25	0.00	-	-	0.13
Giles	2.31	0.12	0.00	0.61	1.46	0.24
Larsen	1.34	0.45	0.00	0.07	1.08	-0.27
Mean	1.97	0.21	0.00	0.63	1.51	-0.07
Combined						
Atkinson	2.72	0.04	0.03	1.12	1.85	-0.17
Downman	1.50	0.16	0.00	0.56	0.74	0.07
Giles	2.16	0.11	0.00	0.46	1.64	0.05
Larsen	2.48	0.07	0.00	0.86	1.08	0.49

K_{total}, total generation mortality; k_3, failure of larvae to pupate in autumn; k_4, pupal parasitism; k_5, missing and eaten pupae measured in winter; k_{0+1}, missing eggs and small larvae measured in spring; k_2, missing and dead larvae during the period spring to late summer. Values for k_6, failure of pupae to eclose, and k_e, larval carryover in spring, were small and are not given.

[a] k_5 and k_{0+1} could not be estimated because no pupal cases were found.

There was no consistent difference between trash and standard treatments in total generation mortality K_{total} (see also Figure 8b) or in the components of mortality within the generation (Table 22). The main components of mortality were missing and eaten pupae (k_5) and disappearance of eggs and small larvae (k_{0+1}). Populations declined at three of the four farms during this generation from second to third ratoon (see also Figure 9a). The increase in population density at the fourth farm, Downman, appears due to the low value for k_{0+1}, ie more small larvae established in spring than expected (Table 22). This may indicate lower true mortality of the early stages, or there may have been some immigration of adult flies, which would decrease the apparent value of k_{0+1}. Regression analysis of the combined data in Table 22 indicated that disappearance and mortality of pupae (k_5) and eggs and small larvae (k_{0+1}) were key factors in population change in the generation (b = 0.44 and 0.72, respectively).

5.3.3.2 Site at Mackay (Craig)

Most pupal cases recovered from the old sugarcane crop at Craig showed signs of damage consistent with invertebrate predation, in marked contrast to cases from the sites in southern Queensland (Table 19). Larval populations were low in the old crop and had not developed significantly in the new crop up to the first ratoon. No analysis was carried out with these data.

5.3.4 Other soil fauna and pathogens

5.3.4.1 Other fauna in soil cores

During processing of soil cores, particular emphasis was given to recording numbers of predatory beetles and beetle larvae (Coleoptera), ie Carabidae and Staphylinidae and larval Elateridae (wireworms), as these are predators of soldier fly larvae or pupae (Robertson and Zalucki 1985). The only other predators that were found regularly in samples were centipedes. Ants occurred frequently, but their role is uncertain. Earthworms and earthpearls (margarodids) were ubiquitous and were also counted.

There was no significant difference between individual treatments in numbers of predatory Coleoptera, centipedes or ants, in any crop year or averaged over all years (Table 23). In the second ratoon, the density of ants was significantly greater in the three early-plant treatments than in the three late-plant treatments ($P_{contrast} = 0.024$) but otherwise there was no difference between fallow lengths for any of these groups in any year. Earthworms were particularly abundant in mill mud plots in all ratoon crops and in the trash plot in the third ratoon, presumably as a response to increased levels of organic matter. Densities of earthpearls did not differ significantly between treatments or fallow lengths in either the plant crop or the first ratoon; they were not measured in later years.

Soil fauna differed greatly between farms (Table 24). There was no obvious relationship between these numbers and the population dynamics of soldier fly at each site. Soldier fly populations developed rapidly at Bengtson and slowly at Downman and particularly Giles, but these observations do not seem to be explained by the densities of any of the groups in Table 24, as judged by the average density for the plant crop and three ratoons.

Factors affecting mortality of soldier fly were further examined by correlation between K_{total} and densities of other faunal groups in every ratoon crop. Using results from individual plots, K_{total} was positively correlated with ant density ($r = 0.22$, $P = 0.045$) but not with the density of any other group ($P > 0.05$). Using results from each farm with densities pooled across treatments, K_{total} was positively correlated with density of predatory Coleoptera ($r = 0.47$, $P = 0.049$), while positive correlations with densities of ants ($r = 0.45$) and wireworms ($r = 0.44$) just failed to reach statistical significance ($P = 0.063$ and 0.065, respectively).

Table 23: Densities of soil fauna in different treatments in successive crop years in six trials in southern Queensland

Crop	Group	Number m^{-2}						*P*
		Bare fallow	Soy-bean	Spray-out	Std.	Trash	Mill mud	
P	Coleoptera [a]	8.8	7.5	12.6	5.0	5.0	10.0	0.53
	Centipedes	2.5	10.0	11.3	3.8	1.3	2.5	0.28
	Ants	1.3	208.5	0.0	17.6	6.3	5.0	0.52
	Earthworms	7.5	52.8	27.6	10.0	6.3	6.3	0.21
	Earthpearls	414	656	1050	683	688	386	0.72
1R	Coleoptera [a]	3.8	8.8	6.3	6.3	9.0	7.5	0.81
	Centipedes	6.3	1.3	7.5	1.3	3.0	2.5	0.22
	Ants	0.0	1.3	5.0	2.5	12.1	15.1	0.34
	Earthworms	8.8 b	10.0 b	20.1 b	17.6 b	43.7 b	162.0 a	0.001
	Earthpearls	986	468	927	692	868	579	0.22
2R	Coleoptera [a]	10.1	6.3	12.6	6.3	8.8	10.0	0.66
	Centipedes	2.5	3.8	3.8	1.3	1.3	3.8	0.59
	Ants	23.9	23.9	3.8	26.4	282.6	37.7	0.07
	Earthworms	31.4 b	22.6 b	44.0 b	35.2 b	54.0 b	223.6 a	0.011
	Earthpearls	na	na	na	na	na	na	
3R	Coleoptera [a]	17.6	18.8	22.6	10.0	20.1	20.1	0.45
	Centipedes	2.5	1.3	2.5	2.5	1.3	2.5	0.98
	Ants	10.0	54.0	31.4	8.8	214.8	50.2	0.50
	Earthworms	59.0 c	26.4 bc	55.3 c	15.1 c	91.7 ab	92.9 a	0.002
	Earthpearls	na	na	na	na	na	na	
P-3R	Coleoptera [a]	10.0	10.4	13.5	6.9	10.9	11.9	0.36
	Centipedes	3.5	4.1	6.3	2.2	1.9	2.8	0.24
	Ants	8.8	71.9	10.0	13.8	49.4	27.0	0.16
	Earthworms	26.7 b	27.9 b	36.7 b	19.5 b	47.1 b	121.2 a	0.002
	Earthpearls [b]	700	562	988	688	825	482	0.34

[a] Carabidae, Elateridae and Staphylinidae.
[b] Plant and first ratoon only.
Means within rows followed by the same letter were not significantly different ($P < 0.05$).

Table 24: Densities of soil fauna on different farms in successive crop years in six trials in southern Queensland

Crop year and group	Number m^{-2}						*P*
	Atkinson	**Bengtson**	**Down.**	**Doyle**	**Giles**	**Larsen**	
Plant							
Coleoptera [a]	3.8	8.8	5.0	18.8	7.5	5.0	0.09
Centipedes	7.5	7.5	7.5	0.0	5.0	3.8	0.37
Ants	15.1	0.0	221.1	0.0	1.3	1.3	0.13
Earthworms	32.7	7.5	20.1	10.0	5.0	35.2	0.34
Earthpearls	517 bc	63 d	1989 a	1010 ab	266 c	31 d	0.000
1R							
Coleoptera [a]	2.5	13.8	2.5	12.6	6.0	3.8	0.08
Centipedes	11.3 a	3.8 b	0.0 b	2.5 b	1.5 b	2.5 b	0.020
Ants	3.8 b	1.3 b	27.6 a	0.0 b	0.0 b	1.3 b	0.006
Earthworms	51.5	5.0	56.5	106.8	12.1	25.1	0.064
Earthpearls	1130 ab	280 bc	1473 a	1223 a	243 bc	80 c	0.001
2R							
Coleoptera [a]	17.6 a	5.0 bc	7.5 abc	8.8 abc	12.6 ab	2.5 c	0.047
Centipedes	6.3 a	5.0 ab	0.0 c	0.0 c	3.8 abc	1.3 bc	0.009
Ants	84.2 a	7.5 bc	128.1 abc	0.0 c	175.8 ab	2.5 c	0.011
Earthworms	99.2 a	57.8 a	90.4 a	94.2 a	67.8 a	1.3 b	0.001
Earthpearls	na	na	na	na	458	90	-
3R							
Coleoptera [a]	20.1 b	44.0 a	7.5 c	15.1 bc	10.0 bc	12.6 bc	0.003
Centipedes	5.0	1.3	1.3	0.0	0.0	5.0	0.13
Ants	41.4 ab	79.1 ab	7.5 bc	15.1 abc	226.1 a	0.0 c	0.044
Earthworms	13.8 d	17.6 bcd	38.9 bc	212.3 a	44.0 b	13.8 cd	0.000
Earthpearls	na	na	na	na	371	211	-
Plant-3R							
Coleoptera [a]	11.0 ab	17.9 a	5.7 bc	13.8 ab	9.0 abc	6.0 c	0.026
Centipedes	7.5 a	4.4 ab	2.2 bc	0.6 c	3.0 bc	3.1 bc	0.006
Ants	36.1 a	22.0 a	96.1 a	3.8 b	16.2 a	1.3 b	0.000
Earthworms	49.3 b	22.0 b	51.5 b	105.8 a	28.6 b	18.8 b	0.004
Earthpearls [b]	824 ab	171 c	1731 a	1117 a	259 bc	49 d	0.000

[a] Carabidae, Elateridae and Staphylinidae.
[b] Plant and first ratoon only.
Means within rows followed by the same letter were not significantly different ($P < 0.05$).

5.3.4.2 Other fauna in pitfall traps

For counts of soil fauna collected in pitfall traps in the second ratoon, only one significant difference was detected between treatments; more ants were collected from each of the three early-plant treatments than from the late-plant treatments (Table 25). The same result was also found for ants collected in soil cores in the second ratoon (see previous section). Catches of most faunal groups in pitfall traps differed significantly between farms (Table 26).

Table 25: Numbers of potential predators in pitfall traps in second ratoons, in different treatments in six trials in southern Queensland

Group	Number/trap/7 d						*P*
	Bare fallow	Soy-bean	Spray-out	Std.	Trash	Mill mud	
Carabids	0.22	0.17	0.16	0.20	0.15	0.25	0.52
Staphylinids	0.31	1.10	0.20	0.28	0.15	0.39	0.47
Thyreocephalus	0.03	0.03	0.02	0.03	0.03	0.08	0.38
Coleoptera [a]	0.81	1.42	0.60	0.75	0.46	0.83	0.66
Centipedes	0.12	0.12	0.29	0.22	0.12	0.23	0.46
Ants	9.19 b	11.87 b	12.62 b	31.13 a	45.73 a	34.05 a	0.001
Spiders	9.22	7.85	5.81	3.74	7.09	5.53	0.89
Earwigs	1.51	1.20	1.60	1.33	3.04	1.59	0.95

[a] Carabidae, Staphylinidae, and Elateridae.
Means within rows followed by the same letter were not significantly different ($P < 0.05$).

Table 26: Numbers of potential predators in pitfall traps in second ratoons, on different farms

Group	Number/trap/7 d						*P*
	Atkinson	Bengtson	Down.	Doyle	Giles	Larsen	
Carabids	0.12 cd	0.39 a	0.26 ab	0.24 bc	0.11 cd	0.03 d	0.000
Staphylinids	0.18 b	0.08 b	0.25 b	1.72 a	0.11 b	0.09 b	0.000
Thyreocephalus	0.01 b	0.00 b	0.09 a	0.10 a	0.01 b	0.00 b	0.001
Coleoptera [a]	0.44 c	0.56 bc	1.19 ab	2.19 a	0.29 c	0.19 c	0.000
Centipedes	0.11 bc	0.15 bc	0.26 ab	0.39 a	0.16 bc	0.03 c	0.017
Ants	13.53 b	19.56 b	45.08 a	0.92 c	20.99 b	44.52 a	0.000
Spiders	4.87 ab	6.53 ab	9.23 ab	11.72 a	3.39 b	3.50 b	0.137
Earwigs	0.76 bcd	0.37 cd	0.80 bc	7.11 a	0.29 d	0.94 b	0.000

[a] Carabidae, Staphylinidae, and Elateridae.
Means within rows followed by the same letter were not significantly different ($P < 0.05$).

These numbers were examined for their possible effect on K_{total} by correlation. The value of K_{total} used was that from the second to the third ratoon, straddling the time when the pitfall collections were made. Using individual plot data, K_{total} was negatively correlated with catches of the staphylinid *Thyreocephalus* ($r = -0.34$, $P = 0.044$), click beetles (Elateridae) ($r = -0.40$, $P = 0.015$), predatory beetles ($r = -0.38$, $P = 0.021$), centipedes ($r = -0.35$, $P = 0.035$) and spiders ($r = -0.34$, $P = 0.041$). Using farm data averaged over treatments, K_{total} was negatively correlated with catches of predatory beetles ($r = -0.83$, $P = 0.042$) and centipedes ($r = -0.89$, $P = 0.019$). None of these negative correlations provides supporting evidence for higher abundance of these groups leading to increased soldier fly mortality due to predation.

The same pitfall catches were also examined for any relationships with soldier fly densities, measured earlier in the second ratoon or later in the third ratoon. There were no significant correlations ($P > 0.05$) with soldier fly densities in the second ratoon, using individual plot data or farm data averaged over treatments. Soldier fly densities in the third ratoon were positively correlated with earlier catches of carabids ($r = 0.39$, $P = 0.019$), predatory beetles ($r = 0.34$, $P = 0.045$) and spiders ($r = 0.37$, $P = 0.025$), using data from each plot; the only significant negative correlation was with the catch of ants ($r = -0.45$, $P = 0.006$) (Figure 10). With data averaged over treatments, densities of soldier fly on each farm in the third ratoon were not significantly correlated with catches of any of the other faunal groups ($P > 0.05$), although the correlation with ants just failed to reach statistical significance ($r = -0.77$, $P = 0.072$).

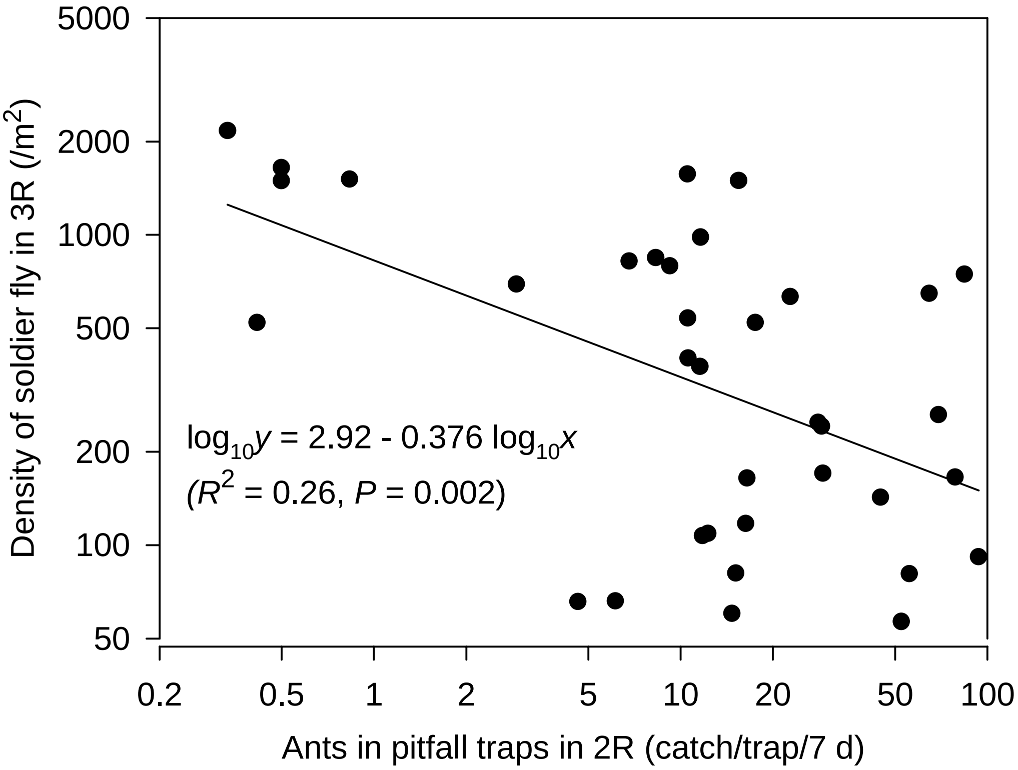

Figure 10: Relationship between density of soldier fly larvae in plots in young third ratoons and numbers of ants captured previously in pitfall traps late in the second ratoon

Wasps known to parasite soldier fly pupae were collected in pitfall traps at Atkinson in the second ratoon. Two species of *Neurogalesus* (Hymenoptera: Diapriidae) were identified, *N. militis* and *N. carinatus*. A total of 101 *N. militis* were collected in traps, with none found on 26 February (after 11 d trapping), one on 11 March (after 13 d trapping, 0.03/trap/wk), nine on 24 March (after 13 d trapping, 0.27/trap/wk) and 91 on 27 April (after 34 d trapping, 1.10/trap/wk). All were females. Four males and one female of *N. carinatus* were collected, all on 27 April after 34 d trapping.

Adult soldier flies were also collected in traps. At Atkinson, average numbers/trap/wk found on successive occasions were 0.0, 0.4, 0.1, and 2.3 on 26 February, 11 March, 24 March and 27 April, respectively. Catches of parasitoids reached high numbers at a similar time to the flight time of soldier fly; presumably the parasitoids were searching for soldier fly pupae which appear several weeks before the adult flies.

Numbers of *N. militis* on 27 April differed between treatments ($P = 0.011$) (Table 27). However, this analysis was based on the pseudo-replicates of pitfall traps within each plot; differences in the table could reflect site variations within the trial rather than effects of treatment. Numbers of *N. militis* were not correlated with density of soldier fly larvae in the same plots in the second ratoon (rank correlation = 0.77, $P = 0.072$), density of larvae of the previous soldier fly generation, ie in the first ratoon (rank correlation = 0.14, $P = 0.79$), with the change in soldier fly numbers in the next generation, ie between the second and third ratoon (rank correlation = 0.60, $P = 0.21$), or with numbers of adult soldier flies in traps on 27 April (rank correlation = 0.77, $P = 0.072$). However, correlations were based on only six data points so the chance of finding a statistically significant result was slight. The largest number of *N. militis* was collected in the bare fallow plot with the largest numbers of adult soldier flies in traps, while the trash and sprayout plots which had few *N. militis* also had few soldier flies (Table 27).

Table 27: Mean numbers of *N. militis* and soldier fly in pitfall traps at Atkinson on 27 April 1999 after 34 days trapping

Species	Bare fallow	Soybeans	Sprayout	Standard	Trash	Mill mud
N. militis	11.3 a	4.3 ab	0.7 c	8.0 a	3.0 bc	4.0 ab
Soldier fly	22.0 a	15.7 ab	7.7 cd	9.0 bc	3.0 d	10.7 bc

Means in rows followed by the same letter are not significantly different ($P = 0.05$).

Interestingly, the density of soldier fly larvae in the second ratoon and numbers of adult flies in traps on 27 April were perfectly correlated on ranks ($r = 1.0$), but there was a very poor correlation between adult catches and density of larvae in the subsequent third ratoon ($r = 0.14$).

5.3.4.3 *Metarhizium anisopliae*

Table 28: Levels of *Metarhizium anisopliae* in soil in different treatments in successive sugarcane crops

Year	Spore concentrations x 10^3/g soil wet weight							
	Bare	Soy	Spray	Std.	Trash	Mud	Bare Inter	Spray Inter
Atkinson								
P	5.7	0.8	0.5	0.0	1.1	0.0	na	na
1R	0.1	0.0	0.1	0.6	0.2	0.2	0.0	0.1
2R	0.3	1.0	0.7	0.2	53.3	0.2	0.3	0.2
Bengtson								
P	1.1	1.6	6.7	1.0	0.8	0.3	na	na
1R	0.4	0.8	0.3	2.1	0.7	1.1	0.5	0.2
2R	0.3	0.9	7.3	0.4	0.6	34.5	1.0	0.2
Downman								
P	1.5	1.1	22.3	0.6	0.1	0.4	na	na
1R	0.4	0.1	0.1	0.5	0.2	0.4	0.3	0.0
2R	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Doyle								
P	22.3	4.5	19.0	9.8	16.0	5.2	na	na
1R	0.8	2.0	2.7	2.9	1.0	na	1.8	0.5
2R	0.7	14.5	0.2	5.9	0.8	1.3	1.1	1.7
Giles								
P	0.1	6.3	5.5	3.2	2.2	5.3	na	na
1R	0.2	0.5	13.7	0.7	(0.8)	1.5	0.0	0.5
2R	0.5	1.2	21.8	6.4	0.5	1.9	na	0.8
Larsen								
P	1.0	1.7	6.8	1.0	0.8	1.0	na	na
1R	0.1	0.1	0.0	0.2	0.2	0.5	0.1	0.1
2R	9.8	0.6	0.4	0.2	19.5	0.5	0.1	0.1
Craig								
P								
1R	0.1	0.1	0.2	(0.1)	0.2	0.1	0.0	0.0
2R	na	na	na	na	na	na	na	na
Mean in southern Qld. (excl. Craig)[a]								
P	5.3 b	2.7 b	10.1 a	2.6 b	3.5 b	2.0 b	na	na
1R	0.3	0.6	2.8	1.2	0.5	0.7	0.5	0.2
2R	2.0	3.1	5.1	2.2	12.5	6.4	0.5	0.5

[a] *P* by analysis of variance in 1997, 1998 and 1999 was 0.030, 0.17 and 0.68, respectively. Means followed by the same letter were not significantly different ($P < 0.05$). Bracketed values on farms in the first ratoon corresponded to plots having incorrect trash treatments and were not included in means or statistical analysis.

Metarhizium anisopliae is the only pathogen of soldier fly commonly recorded under field conditions in Australia (Allsopp and Robertson 1988). Its incidence is often low (Robertson and Zalucki 1985), but Samson and McLennan (1993) measured rates of infection sufficient to greatly reduce local densities of larvae within one canefield.

Mean soil concentrations of spores of *Metarhizium* within cane rows in the plant crop were significantly higher where the old crop had been killed with herbicide and the new crop planted with minimal soil disturbance, than in all other plots (Table 28). Cultivation may have had an adverse effect on spore survival, or may have moved spores out of the sampling depth. Alternatively, concentrations of spores in the new crop rows in the sprayout plots may have been high because the crop was planted back into the old planting rows, whereas the old and new rows probably did not coincide in other treatments. Whatever the reason, the higher levels of *Metarhizium* in the sprayout plots indicate that this management practice together with minimum-tillage planting may help to conserve insect pathogens in the root zone.

Mean concentrations of spores of *Metarhizium* in soil in the first and second ratoons did not differ significantly between treatments (Table 28). However, levels in the first ratoon tended to be highest in the sprayout-minimum tillage treatment. Spore concentrations were also measured in the centre of the interrows in two treatments in ratoon crops. In the first ratoon, levels were lower in the interrow samples than in the row samples in the sprayout treatment ($P_{contrast}$ = 0.023) but not in the bare fallow treatment ($P_{contrast}$ = 0.91), which is in agreement with minimum-tillage planting into the old rows having maintained spores that had already accumulated beneath the old stools. There was no significant difference between row and interrow concentrations of spores in either the sprayout or bare fallow treatments in the second ratoon ($P_{contrast}$ = 0.24 and 0.74, respectively).

5.3.5 Soil nutrient levels in 2000

Soil from the six southern trials was analysed for the chemical parameters listed in Table 29, after the second ratoon harvest. Three trials, Atkinson, Bengtson and Doyle, had been ploughed out after harvest and were fallow when samples were taken, while the other three trials were still growing cane. Statistically significant differences were found between treatments for only three measurements, potassium, zinc and total nitrogen. In each case, levels were higher in mill mud plots than in other treatments; mean levels were 0.231 and 0.124 me%, 4.10 and 2.53 mg/kg, and 0.138 and 0.125% for K, Zn and N, respectively, for mill mud and for all other treatments combined. Surprisingly, levels of phosphorus were not significantly higher in mill mud plots (P = 0.091), but results were extremely variable across farms. Measured levels of P were higher in mill mud plots than in other plots on most farms and were extremely high at Larsen (484 mg/kg), but were relatively low at Atkinson (22 mg/kg).

All measurements except zinc differed significantly between farms (Table 29). Although there was no significant difference between phosphorus levels on farms across all plots, levels differed significantly when mill mud plots were excluded from the analysis.

Table 29: Results of chemical analyses of soil samples collected from different farms in June 2000, pooled across treatments

Analysis	Atkinson	Bengtson	Downman	Doyle	Giles	Larsen	*P*
pH	6.41 b	6.36 b	6.50 b	5.60 c	6.78 a	6.94 a	0.000
SEC (dS/m)	0.046 ab	0.035 cd	0.056 a	0.031 d	0.042 bc	0.032 d	0.000
Ca (me%)	7.07 b	9.25 a	4.57 c	4.88 c	9.52 a	9.30 a	0.000
Mg (me%)	11.25 a	8.56 c	2.53 d	3.08 d	8.75 c	10.13 b	0.000
Na (me%)	0.437 b	0.415 b	0.496 b	0.185 c	0.680 a	0.684 a	0.000
K (me%)	0.130 b	0.136 b	0.113 b	0.253 a	0.133 b	0.084 b	0.000
P (mg/kg)	21.3	18.5	40.5	48.5	48.7	110.7	0.288
P (mg/kg) [a]	21.2 bc	16.2 c	25.4 bc	39.2 ab	45.8 a	36.0 ab	0.020
S (mg/kg)	12.67 a	9.67 abc	7.00 bcd	10.50 ab	5.83 cd	4.17 d	0.003
Cu (mg/kg)	4.22 b	3.79 b	0.51 d	2.32 c	4.93 a	4.32 b	0.000
Zn (mg/kg)	2.98	3.11	2.42	3.37	3.09	1.80	0.111
Fe (mg/kg)	34.8 b	32.2 b	34.8 b	148.7 a	31.7 b	40.7 b	0.000
Mn (mg/kg)	51.8 a	49.5 a	17.3 b	43.8 a	52.5 a	51.7 a	0.000
Bo (mg/kg)	0.397 c	0.355 cd	0.550 a	0.387 cd	0.482 b	0.333 d	0.000
CEC (me%)	18.2 a	19.8 a	5.8 c	10.4 b	19.5 a	19.9 a	0.000
Total N (%)	0.133 b	0.128 b	0.095 c	0.092 d	0.187 a	0.128 b	0.000
Org. C (%)	2.21 b	2.07 b	2.28 b	1.23 c	2.64 a	2.11 b	0.000
Av. Si (mg/kg)	86.2 a	85.0 a	10.3 d	28.3 c	59.0 b	79.2 a	0.000

[a] Excluding mill mud treatment.
Means within rows followed by the same letter not significantly different ($P < 0.05$).

Possible relationships between nutrient levels and soldier fly densities were examined by correlation. An average soldier fly density over three ratoon crops was calculated for each plot in each southern trial, as an index of the suitability of the soil for soldier fly. Average densities in each plot ($n = 36$) were positively correlated with levels of sulphur ($r = 0.52$, $P = 0.001$), available silicon ($r = 0.49$, $P = 0.003$), potassium ($r = 0.46$, $P = 0.005$) and magnesium ($r = 0.35$, $P = 0.039$), and negatively correlated with levels of sodium ($r = -0.50$, $P = 0.002$) and boron ($r = -0.39$, $P = 0.020$) and with pH ($r = -0.45$, $P = 0.006$).

5.3.6 Analysis of crop yields

Mean plant crop yields as both cane and sugar, and gross return, were greater for the short fallow plots than for the long fallow plots in the six trials in southern Queensland (Table 30). Within the long fallow treatments, plots planted with minimum tillage after either sprayout of the old ratoon or after a soybean rotation produced identical plant crop yields to conventionally cultivated plots.

First ratoon crop yields were not collected for one of the trials because of wet weather. Cane yield did not differ significantly between treatments in the remaining five trials (Table 30). Levels of ccs were greatest in the trash-blanketed plots among the short fallow treatments, and this was reflected in sugar yield and monetary returns. Sugar yields and monetary returns in the bare fallow and soybean treatments were higher than in all short fallow treatments excepting the trash blanket.

In the second ratoon, no significant differences were detected between treatments for cane yield, ccs, sugar yield or monetary return, averaged over the six trials (Table 30).

Table 30: Yield and gross return of six southern trials over a crop cycle of the plant crop and two ratoons

Variable	Long fallow – late plant			Short fallow - early plant			*P*
	Bare fallow	Soybeans	Sprayout	Std.	Trash	Mill mud	
Plant							
Cane (t/ha)	102 b	101 b	101 b	124 a	130 a	127 a	0.000
ccs	15.5 bc	15.6 bc	15.4 c	16.0 ab	16.3 a	15.8 abc	0.001
Sugar (t/ha)	15.7 b	15.8 b	15.5 b	19.8 a	21.2 a	20.1 a	0.000
Return ($/ha)[a]	2949 c	2974 c	2891 c	3786 b	4091 a	3820 ab	0.000
1R (5 trials)							
Cane (t/ha)	87	86	78	72	87	80	0.067
ccs	15.0 ab	14.9 ab	14.6 bc	14.5 bc	15.4 a	14.1 c	0.024
Sugar (t/ha)	13.1 ab	12.9 ab	11.6 bc	10.6 c	13.6 a	11.4 c	0.011
Return ($/ha)[a]	2411 ab	2393 ab	2113 bc	1918 c	2559 a	2032 c	0.005
2R							
Cane (t/ha)	82	86	82	86	89	90	0.912
ccs	15.2	15.4	15.3	15.6	15.4	15.1	0.166
Sugar (t/ha)	12.5	13.2	12.6	13.5	13.6	13.6	0.918
Return ($/ha)[a]	2329	2479	2353	2546	2538	2514	0.908
Sum, P-2R (5 trials)							
Cane (t/ha)	272 ab	273 ab	254 b	286 a	296 a	295 a	0.034
ccs	15.3 b	15.3 b	15.1 bc	15.4 ab	15.6 a	14.9 c	0.002
Sugar (t/ha)	41.6 bc	41.8 bc	38.5 c	44.4 ab	46.6 a	44.7 ab	0.006
Return ($/ha)[a]	7774 bc	7816 bc	7164 c	8372 ab	8848 a	8289 ab	0.002

Means within rows followed by the same letter not significantly different ($P < 0.05$).
[a] Gross, assuming a sugar price of $330/t and a harvesting cost of $5.30/t.

Over a crop cycle of plant and two ratoon crops, highest yields and returns came from a short fallow (Table 30). The standard treatment produced 19.4 t/ha more cane, 3.8 t/ha more sugar and $787/ha greater return than the average of the three long fallow treatments ($P_{contrast}$ = 0.08, 0.02 and 0.01, respectively). The trash treatment was very successful, and further improvements in yield under a trash blanket could undoubtedly be made with more attention to row profiles, interrow cultivation and fertilising, on individual farms. The mill mud treatment suffered with low ccs.

There was not a significant relationship ($P > 0.05$) between yield of each ratoon crop and density of soldier fly larvae measured earlier in the same crop, for the four trials containing Q151 (Figure 11). A linear regression with soldier fly density explained only 2% of the variance in yields in the first ratoon and none of the variance in the second ratoon. Yields of the trash-blanketed plots were not greatly different from those of burnt plots with comparable numbers of soldier fly (Figure 11). There were not enough data to conduct a similar analysis with Q124.

In the Craig trial at Mackay, mean plant crop yields in short and long fallow plots were 102 and 78 t/ha, respectively, following the same trend as the southern trials. Harvest yields were not measured after the plant crop, and in 1999 the farmer stated he did not want any further involvement with the trial. Conditions were very difficult for harvesting at Mackay in 1999, and the farmer felt that the need to notify BSES of operations in the field was too demanding. No further work was done in this trial, which contained few soldier fly in any case.

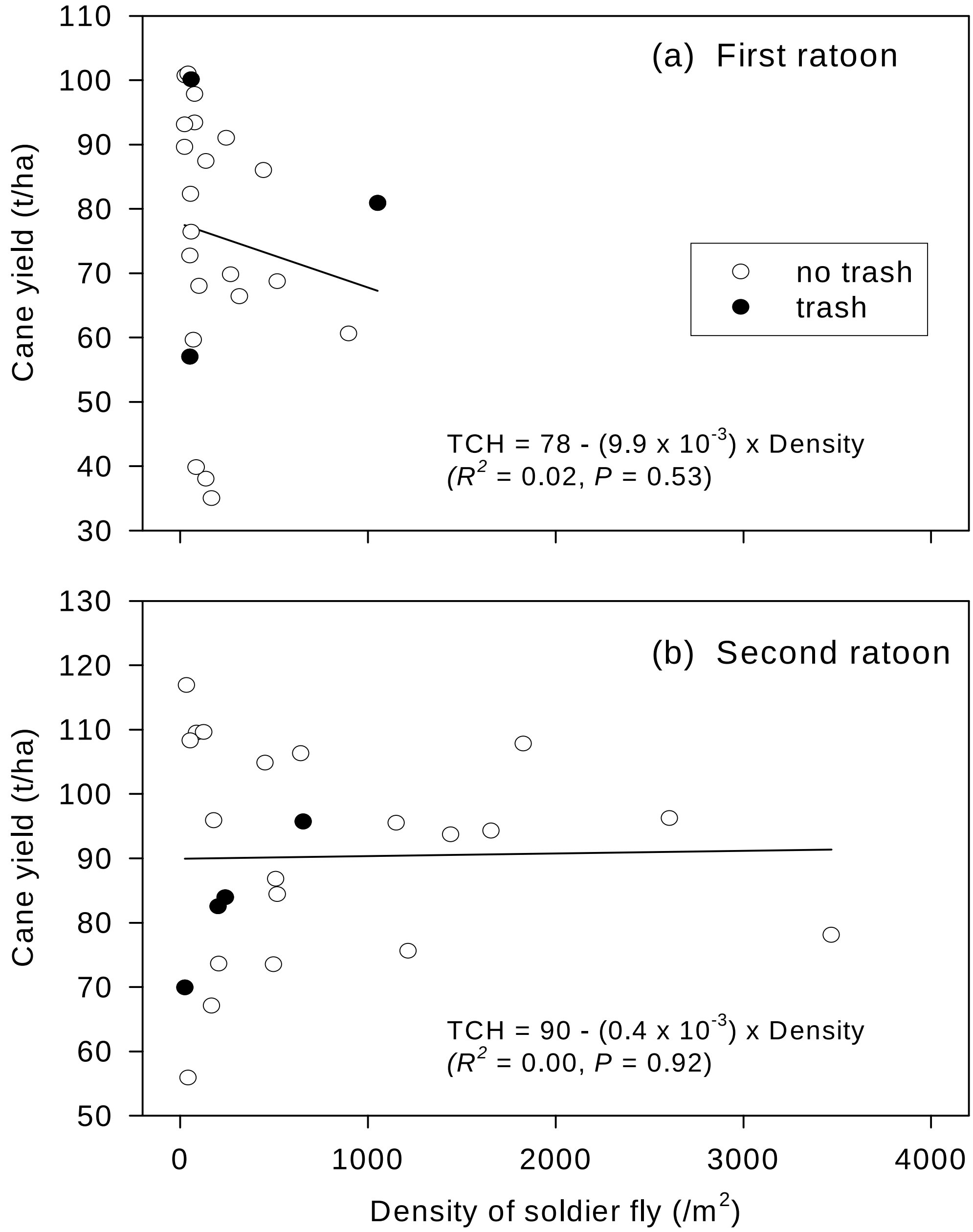

Figure 11: Annual yields of ratoon crops of Q151 and soldier fly densities measured earlier in the same crop

5.4 General discussion

Soldier fly populations were greatly reduced after the break between the old sugarcane crop and establishment of the new crop in the same field. Cultural control of soldier fly has usually targeted pre-plant fallows (Allsopp and Bull 1987). In these trials, I extended the length of the fallow period in some plots by harvesting and destroying old cane crops earlier than is usual practice. This not only added several months to the fallow, but also ensured that the crop was destroyed when larvae were small and probably more vulnerable to starvation. I also extended the fallow by planting some plots late, after the usual adult flight period. Fewer larvae were present in the new plant crop when the fallow was lengthened by both destroying the old crop early and planting late, compared with late crop destruction and early planting.

The difference between fallow lengths could have been due to two factors, higher mortality of existing larvae and lower recruitment of new larvae. More larvae are likely to starve after a long fallow, as they can live several months without food and may survive a short fallow (Hitchcock 1969; Wilson 1970). In New Zealand pastures, recruitment of small larvae into fields was greatly reduced when the ground cover was killed with herbicide just before the adult flight period. Fewer eggs were laid, eggs were less likely to hatch, and survival of small larvae may also have been reduced in bare ground (Kain and Burton 1975). In canefields, fallow ground may be less attractive or favourable for reproduction of flies that emerge from pupae in the same or nearby fields.

This difference between fallow lengths was maintained into the first and perhaps the second ratoon, but by the third ratoon there was no difference between fallow lengths. This suggests two possibilities. There may have been a difference in the dynamics of soldier fly populations between early- and late-plant plots, and perhaps the more rapid establishment of larval populations in the early-plant plots also led to an earlier levelling-off of numbers. Alternatively, there may have been migration of adults between plots, and if so, the effect of late planting may be more permanent if carried out over whole fields.

Past BSES recommendations for soldier fly management have been for severe cultivation methods to destroy the old crop and injure larvae, ploughing in autumn to bury pupae, and surface cultivation during late autumn-early winter to disturb eggs (Allsopp and Bull 1987). However, there has been little or no experimental basis for these recommendations. In the current trials, zero tillage of fallows after killing the old crop with herbicide, and a rotation with soybeans, were both successful at reducing larval numbers where planting was late. Sampling during the fallow in two trials showed living larvae were still present in sprayout plots in March-April, suggesting that early planting would have been inadvisable in these plots

Minimum tillage preserved levels of the pathogen *Metarhizium anisopliae* in the new sugarcane rows. However, *Metarhizium*-infected larvae were not frequently found in the new crop; the pathogen was probably not a factor in soldier fly dynamics, and the strains of *Metarhizium* measured may not have been pathogenic to soldier fly. Otherwise, minimum tillage of fallows did not appear to affect the abundance of other groups of beneficial fauna. Addition of organic matter as trash or mill mud also did not seem to increase the density of predators, although earthworm densities were increased, particularly by mill mud.

Of the potential predators examined, past emphasis has mainly been on coleopterous predators such as carabids, staphylinids and wireworms (Robertson 1984b, 1987; Robertson and Zalucki 1984, 1985). There was little evidence that population density of these predators was a critical factor determining differences in soldier fly densities between the six trials in southern Queensland. There was a negative correlation between values of K_{total} and coleopterous predators in soil cores, using data from all ratoon crops averaged across farms, but this was probably influenced mainly by an increase in both K_{total} and density of predatory Coleoptera in older ratoons; there seemed to be no relationship between the density of soldier fly and predatory Coleoptera on farms. This may not be so everywhere, and the very high frequency of damage to pupal cases in the trial in Mackay was consistent with invertebrate predation, perhaps by Coleoptera, and the soldier fly population remained at a low level thereafter at this site.

The trials suggest that ants may have a more important role than previously thought. Ants are very abundant in many canefields. The normal soil sampling procedure does not give a good indication of their abundance, as ants are highly aggregated in colonies and the ants are very mobile and readily escape during sampling and subsequent sample processing. Pitfall trapping is a much better method for assessing their abundance. The nature of interactions between ants and soldier fly is unknown. Ants seem to coexist with soldier fly larvae beneath cane stools (personal observation), and Robertson and Zalucki (1985) recorded that larvae and pupae are not attacked by ants. However, ants do attack adults and eggs (Robertson 1984b). The disappearance of early stages of soldier fly, which could be affected by predation on adults and eggs, was a key factor in my study. Robertson (1984b) believed that this early stage disappearance was due mainly to failure of newly hatched larvae to find plant roots, but predation by ants cannot be ruled out. The coastal brown ant, *Pheidole megacephala*, is an important biological control agent of cicadas in canefields (Allsopp *et al*. 1993). Ant densities in second ratoons appeared to be affected by the fallowing history of fields, and it is possible that long fallowing had a deleterious effect on colonies, but more research would be required to substantiate this.

There was no evidence that organochlorine levels are having an ongoing role in soldier fly population dynamics at these farms. Levels of dieldrin and BHC were mostly low, and heavy infestations of soldier fly were recorded on farms with negligible residues (eg Atkinson, Bengtson) and significant residues (eg Doyle).

Correlations were found between soldier fly densities and levels of some nutrients in soil. These correlations may be spurious, but some could be worthy of further investigation in controlled experiments.

Cane yields over a crop cycle of a plant crop and two ratoons were consistently lower where cane was planted late after a long fallow than where it was planted early. Differences could have arisen between treatments because of the planting equipment and procedure. A conventional planter was used on the early-plant plots, whereas a planter modified for minimum-tillage planting was used on all late-plant plots, even those that had been cultivated conventionally during the fallow. However, the main reason for the difference between planting times is likely to have been the longer growing time of the early planted cane. Lower soldier fly populations in late-planted cane were not sufficient to negate this inherent disadvantage in yield.

Although fields produced less yield after a long fallow in my trials, the consistently lower numbers of soldier fly larvae in plant and first ratoon crops should reduce risk to those crops. Some crops affected by soldier fly can fail to ratoon after only one or two harvests, if no preventative steps are taken. This is unlikely to occur if fields are correctly long fallowed, with either spraying out with herbicide or rotation with soybeans being the preferred options.

Crop yields across trials and plots could not be related to the soldier fly density in each plot. Previous studies have shown that such a relationship exists. In the current trials, other factors, and especially water, obscured any relationship. Soldier fly density is only one of a range of factors that must be addressed to improve yields, and yields can be surprisingly high with soldier fly present, at least using Q151 which may have some tolerance to the pest.

In summary, long fallowing by combining crop destruction early in the harvest season with planting late the following year was effective in reducing soldier fly numbers in plant and early ratoon crops. Early crop destruction is not popular with cane farmers, who prefer to wait until all fields have been harvested before deciding which crops to destroy. However, late planting is acceptable to farmers with soldier fly problems and many have already adopted the practice. There was a cost to late planting, due to reduced yields of the plant crop caused by the shorter growing period. In my trials, the late-plant plots did not make up this yield in the subsequent two ratoon crops, and by the third ratoon there was no difference in soldier fly populations between planting times. Nevertheless, late planting might have maintained its superiority over early planting if carried out on a larger scale where there was less opportunity for immigration of adult flies. Late planting with or without early crop destruction should avoid the possibility of crop failures in young ratoons, and is one way of reducing risk in soldier fly prone fields. Crop management procedures to minimise the subsequent rate of increase of soldier fly populations have still not been identified.

6.0 KILLING LARVAE IN FALLOWS

6.1 General introduction

Cultural control of soldier fly has usually targeted pre-plant fallows (Allsopp and Bull 1987), as this is the only time many cultural measures can be implemented. Although soldier flies do not cause crop damage in the first year or two after planting, it is assumed that larvae present at planting may be progenitors of larger numbers in future ratoons.

Past BSES recommendations have been for severe cultivation methods to destroy the old crop and injure larvae, ploughing in autumn to bury pupae, and surface cultivation during late autumn-early winter to disturb eggs (Allsopp and Bull 1987). There is little or no experimental basis for these recommendations, and they may in fact encourage future soldier fly problems by destroying natural control agents. Also, bare fallowing in summer is inappropriate in many areas because of the risk of erosion. Five field trials and one pot experiment were carried out to evaluate alternative strategies for disinfesting ground between crop cycles of sugarcane.

6.2 Methods of stool destruction

6.2.1 Introduction

One trial was established to determine whether soldier fly larvae could be killed by different implements or chemicals when crops are destroyed at the end of a cropping cycle.

6.2.2 Materials and methods

An infested ratoon due to be destroyed was identified near Bundaberg (Piper). Five treatments were applied with the following sequences of implements or chemical applications:

1. “Plough” – ripping tine, offset disc, plough.
2. “Rotary” – ripping tine, rotary hoe, ripping tine, rotary hoe.
3. “Rotary row” – ripping tine, rotary hoe in row only, ripping tine, rotary hoe in row only.
4. “Vapam” - rotary hoe in row only, Vapam in row @ 105 L/ha.
5. “Vapam check” - rotary hoe in row only.

The first treatment, ripping, discing and ploughing, represented a ‘gentle’ method of removing the old ratoon stools, whereas rotary hoeing was intended to physically kill soldier fly larvae. Rotary hoeing of the row alone was intended to obtain the benefit of killing larvae in the rows, where almost all soldier fly larvae are concentrated (Samson and McLennan 1992b), without needing to disturb the interrows. Vapam (metam-sodium) is a liquid biocide that has caused high mortality of soldier fly larvae in pot experiments (unpublished data); in soil it converts to methyl isothiocyanate which has some fumigating action. Vapam was only applied beneath the rows, to minimise cost. The row had to be cultivated first with a single pass of a rotary hoe, to allow penetration of the Vapam injector and to aid gaseous diffusion through the soil. The Vapam check treatment was included to separate any effect of Vapam from that of the prior rotary hoeing.

Each treatment was applied to plots measuring 6 rows by 15 m, with four replications. Treatments were applied during the period 16-18 December 1996. Rotary hoeing was to a depth of about 170 mm; rotary hoeing of the row alone was to a width of 550 mm. Vapam was applied in a band of width of 510 mm beneath the old rows using a winged tine.

Pre-treatment samples consisting of eight soil cores from each plot were taken on 3 December 1996. Soldier fly larvae were counted in these samples. Pre-germinated sorghum plants were planted in each plot on 8 January 1997, to aggregate any surviving larvae for sampling. The effect of treatments was assessed on 11-12 February 1997 by two methods, first, by taking eight soil cores from each plot, and second, by digging up five sorghum plants and their roots from each plot. Live larvae were counted in the samples.

6.2.3 Results and discussion

Sorghum plants were a successful method of sampling soldier fly. More larvae were found beneath the plants than in soil cores taken from other positions in the plots (Table 31).

There was no significant difference between the number of larvae following the different treatments (Table 31).

Table 31: Effect of different procedures at the time of crop destruction on subsequent numbers of soldier fly larvae

Treatment	Pre-treatment count Larvae/8 cores	Post-treatment counts (adjusted for pre-treatment count)	
		Larvae/8 cores	Larvae/5 sorghum plants
Plough	4.8	0.2	4.4
Rotary	6.8	1.7	6.8
Rotary row	2.9	1.3	3.3
Vapam	4.0	0.5	3.5
Vapam check	4.6	1.6	9.3

Analysis of variance; cores $P = 0.53$, sorghum $P = 0.76$.
Analysis of covariance with pre-treatment counts; cores $P = 0.56$, sorghum $P = 0.87$.
Means are back-transformed values after counts had been transformed as $\log(x + 1)$.

The results cast doubt on the effectiveness of cultivation implements to kill soldier fly. The use of a rotary hoe to destroy stools and kill larvae has been recommended in the past. Two passes of a rotary hoe had no more effect than ploughing and discing, which would not be expected to cause much physical injury to soldier fly larvae. Vapam was also ineffective in the trial. The soil surface was not sealed after Vapam injection, so some of the fumigant may have been lost to the air. Vapam may be more effective if the soil surface was sealed immediately after application using a roller or irrigation.

6.3 Further testing of Vapam for disinfestation

6.3.1 Introduction

One trial was established to further assess the value of Vapam (metam-sodium) as a soil treatment at the time of stool destruction in old ratoons. This chemical has shown some potential in pot tests. It was not effective in the previous field trial, but the soil was not sealed after application in that trial.

6.3.2 Materials and methods

An infested ratoon was identified near Gin Gin (Finlay). Vapam was applied on 27 November 1997 at 110 L/ha, in a band of width 510 mm at a depth of about 200 mm in the cane rows using a winged tine. The plots were first rotary hoed to prepare the soil, and the treated zone was then pressed down with a roller and the plots irrigated immediately to seal the soil surface. Plots which were hoed but not treated with Vapam served as Controls. Plots measured 2 rows by 15 m, with five replications.

Pre-treatment samples consisting of four soil cores from each row of each plot were taken on 17 November and larvae counted. Five pre-germinated sorghum plants were planted in each row after treatment on 11 December, to aggregate larvae for sampling, and these plants were then dug up and larvae counted on 13 January 1998. Numbers of soldier fly were transformed as $\log(x + 1)$ before analysis of variance.

6.3.3 Results and discussion

Numbers of larvae were similar before treatment but were lower in the Vapam plots after treatment (Table 32). This difference did not reach statistical significance ($P = 0.11$), mainly because of the small number of error degrees of freedom, but if each row was treated as a replicate then the effect of Vapam treatment was highly significant ($P = 0.003$).

Table 32: Effect of Vapam applied beneath old ratoon stools on subsequent numbers of soldier fly larvae

Treatment	Pre-treatment count (larvae/4-cores)	Live larvae after treatment (larvae/5 sorghum plants)
Control	33	50
Vapam	29	13

The result suggests that Vapam can reduce larval numbers with appropriate application; in this trial the apparent reduction was 70%. More work would be needed to define the optimum application rate, and to determine if there is any long-term benefit of treatment.

6.4 Decline of soldier fly numbers in sprayout fallows

6.4.1 Introduction

Sprayout of ratoons with herbicide was a good management option in large scale trials, in association with a long fallow. The length of time required to starve larvae in sprayed ratoons was assessed in one trial.

6.4.2 Materials and methods

An infested ratoon was located at Mackay (Agius). Three large plots of about 0.2 ha each were marked out, and a central sampling area of 6 rows x 15 m established in each. One plot was sprayed with Roundup (glyphosate 360 g/L) on 26 January 1998, but other plots could not be sprayed on that date because of boggy conditions. All three plots were then sprayed with Roundup on 16 February. Final herbicide sprays of Roundup CT (glyphosate 450 g/L) and Fusilade (fluazifop-P 212 g/L) were carried out on 13 and 21 May, respectively, to kill weeds and surviving cane plants.

Soldier fly larvae were sampled before the old ratoon was sprayed and at intervals thereafter, by collecting four soil cores from around each of 10 cane stools in the central sampling area of each plot.

6.4.3 Results and discussion

Numbers of soldier fly larvae had been greatly reduced but not eliminated by June (Figure 12). Some pupae and pupal cases were found in the May and June samples; these were included in the estimates of population density if they appeared healthy. The apparent reduction in numbers from November to June was 98%. This trial was not a good example of killing cane with herbicide. Initial spraying was late and hampered by wet conditions, and some cane was still alive in May when Fusilade was applied. An earlier and more effective kill of cane stools would almost certainly have given a greater reduction in soldier fly populations, and there is an indication that control was most effective in Plot C, which was sprayed earlier than the other two plots. Regardless, the control of soldier fly was very good in all plots.

No larvae were subsequently found in the plant crop or first ratoon in this trial, using the same sampling procedure.

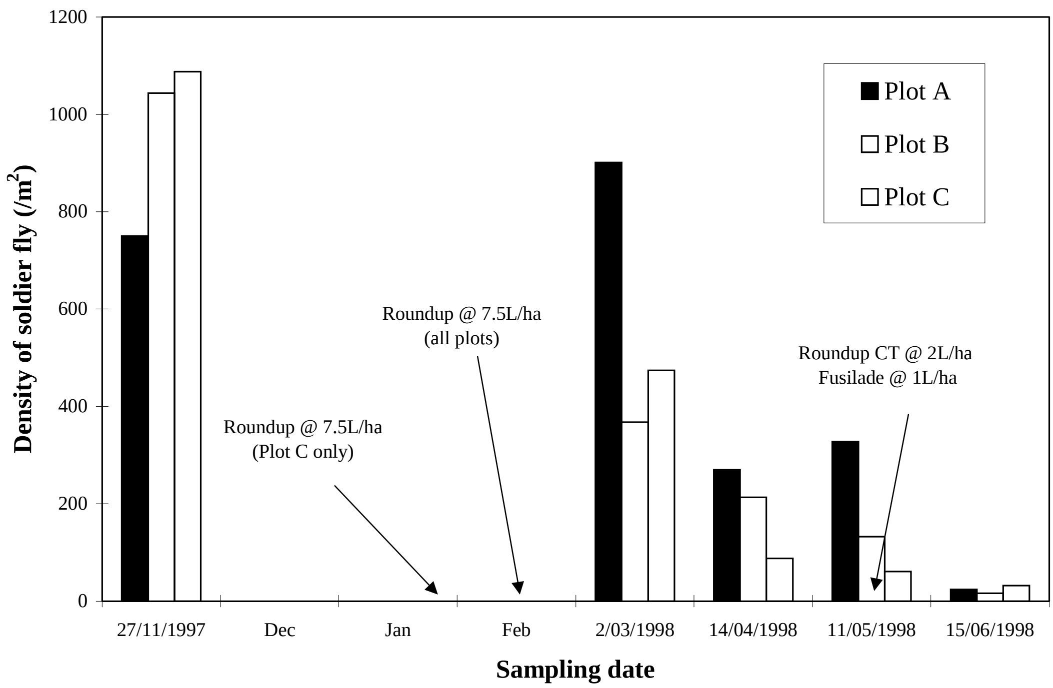

Figure 12: Change in numbers of living soldier fly larvae in plots with cane plants killed by herbicide

6.5 Use of a systemic insecticide plus a lure crop in fallows

6.5.1 Introduction

Carbofuran (Furadan) was one of the best chemicals tested in bioassays against soldier fly (Samson 1992). This product has reduced soldier fly populations and crop damage in New Zealand maize (Robertson 1979). It has previously been tested as a treatment for soldier fly in growing crops of sugarcane, but did not consistently reduce larval numbers when applied in ratoons (Samson and Harris 1994) or in plant cane (unpublished data). However, I thought that Furadan may be more successful if applied in combination with a lure crop such as sorghum, planted into a fallow. In a previous experiment, about 80% of larvae were aggregated around cane plants six weeks after planting (Samson and Harris 1995). With the closer row spacing of sorghum, soldier fly larvae may aggregate around the roots sooner, and so may be affected by the chemical while it is still active in the soil. Furadan is systemic, and so should affect larvae when they feed on the sorghum roots.

6.5.2 Materials and methods

A trial site was located in an infested ratoon due for ploughout at Mackay (Wood). Four treatments were applied, sorghum alone, Furadan alone, sorghum plus Furadan, and a control. Treatments were applied on 17 March 1999 to plots measuring 15 m by 6 m, with five replications. The trial area was worked up to a seed bed and sprayed with Sempra (halosulfuron-methyl) at 100 g/ha and Actril (2,4-D plus ioxynil) at 2 L/ha to control emerged nutgrass and broadleaf weeds before planting sorghum. Treatments were applied using a combine planter with a drill spacing of 31 cm, at rates of 24 kg/ha of sorghum (Jumbo) and 33 kg/ha of Furadan (100 g ai/kg carbofuran). In the sorghum/Furadan treatment, seed and insecticide granules were applied behind the same tine but were metered from different chutes within the combine box. The control comprised planting tines alone with no sorghum or Furadan added.

Soldier fly larvae were sampled by collecting two 4-core samples from each plot, before the old sugarcane crop was cultivated (28 January 1999) and then after establishment of the sorghum crop (7 May 1999). Numbers of live larvae in May were compared between treatments by analysis of variance, using the numbers in the old crop as a covariate. Soldier fly numbers in each sample were transformed as $\log(x+1)$ before analysis.

6.5.3 Results and discussion

Table 33: Effect of an insecticide/sorghum combination on soldier fly numbers in a fallow field

Treatment	Pre-treatment count Larvae/4 cores	Post-treatment count Larvae/4 cores
Control	4.9	1.6
Sorghum	3.2	1.6
Sorghum/Furadan	4.7	2.0
Furadan	4.6	0.6

Numbers of soldier fly larvae were low after treatments had been applied (Table 33). There was no significant difference in numbers between treatments (P = 0.25). A similar experiment had been done in 1994, using a different planting system, with a similar negative result. This strategy does not seem worth pursuing further.

6.6 Pot comparison of break crops

6.6.1 Introduction

Break crops grown in rotation with sugarcane could be useful alternatives to cultivated or herbicide fallows for soldier fly management, using plants that do not support larval feeding or that are toxic to larvae. Larvae did not grow or survive well when supplied only cucurbits such as zucchini in a previous experiment (Samson and McLennan 1992a). Brassicas may also be useful break crops; Hewitt (1969) reported that turnips are not attacked by soldier fly larvae (although there are contrary reports of attack on both turnips and choumoellier, Wilcocks 1971), and isothiocyanates toxic to larvae were isolated from the roots of choumoellier (Lowe *at al*. 1971).

In this pot experiment, I investigated the effect on soldier fly of a range of possible break crops, brassicas, pumpkin (a cucurbit), peanuts, velvet bean and sugarbeet, in comparison with a suitable host plant (sugarcane) or no plant. The effect of plants on larvae was tested by measuring larval growth and survival in pots containing growing plants and by bioassaying leaf material against larvae.

6.6.2 Materials and methods

Nineteen different treatments were compared in pots in a glasshouse (Table 34). These treatments included 13 different lines of brassicas representing seven species, obtained from Dr John Kirkegaard of CSIRO Division of Plant Industry Canberra, plus several other plant species and bare soil. The experiment was first set up in November 1996 but had to be abandoned because of poor survival of many brassicas; it was repeated in January 1997. Larvae were added to plants already established in pots on 14 March 1997, 20/pot with five replications; they were subsequently retrieved on 7-9 May and their survival and growth assessed. In the intervening period, a sample of leaves was taken from plants on 22 April 1997, shredded and incorporated in 100 g of soil at rates of 0.5% and 5% by weight. Another set of larvae was immediately added to this bioassay, 10/container with three replications, and then retrieved on 3-5 June.

6.6.3 Results and discussion

In the pots containing growing plants, there was no significant difference in growth of larvae between the different treatments (Table 34). Because of the late start of the experiment, larvae were already very large and some were presumably fully grown when put into pots (mean weight = 24.4 mg). Therefore, the effect of the different treatments on larval growth is probably poorly estimated. Estimates of the effect of the different treatments on larval survival should be more meaningful, but survival also did not differ significantly between treatments (Table 34). Some species such as pumpkins grew poorly, and numbers of replicates were consequently reduced in the pot test.

In bioassay containers, there was no significant difference in larval survival between treatments when leaf material was incorporated in soil (Table 34). A considerable proportion of larvae pupated and many emerged as adults during the bioassay period of six weeks. Interestingly, significantly more larvae pupated when leaves were incorporated at 5% (51% pupation) that at the lower rate of incorporation (33%) or when no leaf material was added (23%); the reason is unknown. There was no significant difference in pupation in soil containing leaf material from different plant species.

In summary, the results cast considerable doubt on the ability of the crops examined to directly kill soldier fly larvae while the crops are growing or after they are ploughed in. However, this does not mean that they might not be useful in a crop rotation where the emphasis could be on growing a plant that is not a soldier fly host rather than one that is toxic to larvae. Because larvae were near-fully grown when added to pots, the experiment would not have been a good indicator of the ability of larvae to feed on the different plants if there was no direct toxicity.

Table 34: Effect of different plant species on soldier fly larvae

Species	Cultivar	In pots			Larval survival (%) in leaf bioassay [a]	
		n	**Larval survival (/20)**	**Larval growth (mg)**	**0.5%**	**5%**
Brassica napus						
ssp. *olifera*	Lirakotta	5	12.0	2.2	87	85
	Midas	5	13.2	-0.6	100	89
	Striker	4	11.0	-1.1	96	90
ssp. *rapifera*	Doon major	4	10.0	4.1	100	76
	TNG15	3	8.3	-2.6	90	93
B. campestris	TAP	4	11.3	2.2	93	88
B. juncea	Cutlass	2	7.0	2.2	89	93
	Leaf mustard	3	11.0	0.6	97	97
	Siromo	4	12.8	0.4	81	97
B. nigra	91046	4	7.5	-0.7	89	69
B. carinata	BRA1028/79	4	10.8	3.0	82	89
Sinapis alba	Metex	4	10.0	1.0	100	90
Raphanus sativis	Nemex	2	13.5	3.6	96	97
Sugarbeet		2	4.5	6.5	93	93
Peanut	Pinto	5	12.0	4.9	93	87
Velvet bean		5	12.0	1.3	86	97
Sugarcane	Q124	5	9.0	-0.2	100	89
Pumpkin	Qld Blue	1	0	-	90	87
Bare soil		5	13.8	1.2	-	-
(P)			(0.25)	(0.47)	($P_{species}$	0.16)
					(P_{rate}	0.064)
					($P_{interaction}$	0.058)

[a] Survival in soil alone was 93% ($n = 6$)

6.7 Use of brassicas as break crops in fallows

6.7.1 Introduction

Some species of brassicas have attracted interest as break crops for pest and disease management, because they release toxic isothiocyanates in the soil as the crop residues break down after incorporation (Kirkegaard 1999). Thirteen different brassica lines were previously evaluated for their effect on soldier fly larvae in pots and in a bioassay. The results were not promising (see previous section), but it was thought worthwhile to test a small number of species in field plots.

6.7.2 Materials and methods

Three different types of brassica were obtained, each selected by seed companies because of their potential for biofumigation:

- Two lines of Indian mustard, Fumus F-L71 and Fumus F-E75 (Ag-Seed Research).
- One blend of fodder rape, BQ(Bioqure)Mulch™ (Wrightson Seeds).

Five possible trial sites were investigated and pre-treatment samples taken, two at Mackay and three near Bundaberg and Maryborough. The final trial site chosen was near Wallaville c/o Bundaberg (Harris).

Brassicas were planted in plots measuring 10 m by 7 m, with five replications. Unplanted plots served as controls. Soil was cultivated to form a seedbed before planting the brassicas. The herbicide Treflan (trifluralin) was applied at 2.5 L/ha before planting. Based on results of a soil test, fertiliser was applied at rates of 100 kg/ha urea, 150 kg/ha superphosphate and 50 kg/ha Trifos. Seed was then broadcast by hand at 13 kg/ha on 12 November 1999. Soil was wet at the time of sowing, so no subsequent incorporation was carried out.

6.7.3 Results and discussion

Good germination and establishment of brassicas was observed in the plots. However, some of the Fumus plants began flowering in mid-December, when only about 10 cm high, and were senescing by early January (Figure 13). BQMulch™ was dead by early January, with the leaves heavily damaged by insects (Figure 14). The amount of biomass produced by the crops was inadequate; crops of Fumus in southern areas grow to waist height (Ag-Seed Research, pers. comm.). The trial area was cultivated and any remaining plants destroyed in early February.

Numbers of soldier fly in the old sugarcane crop on 20 October 1999 averaged 34 live larvae per 4-core sample. Because of the extremely poor growth of the brassicas, no post-treatment measurement of soldier fly was carried out.

The trial did not succeed in estimating the effect of brassicas on field populations of soldier fly, but it demonstrated the difficulty of using brassicas as a break crop with sugarcane. The brassica lines performed poorly in the early summer. Weather conditions had been extreme, with a very dry period before Christmas and heavy rain soon after. Day length may also have been inappropriate, stimulating early flowering of the Fumus plants, and pest infestations were severe. Planting much earlier (eg August) may give a better crop, but does not suit a rotation for soldier fly management as farmers usually do not destroy fly-infested cane crops until late in the harvest season. Another option would be to sow brassicas in autumn, grow them through winter before incorporation and then plant cane the following spring. This may work, but is probably unnecessary for soldier fly management as very few larvae survive into crops of late-plant cane with appropriate fallowing.

6.8 General discussion

Maintaining a long break from cane by killing the old crop with herbicide was a very effective method of establishing a plant crop almost free of soldier fly larvae. A reduction in soldier fly numbers approaching 100% was achieved between the old and new crops, provided the new crop was planted late. With this level of reduction, there is no need for additional control measures during the fallow period, if farmers are willing to delay planting.

However, late planting does have a cost in cane yield at the first harvest, because of the reduced growing period compared with early planting. Any fallow, whether a short fallow with early planting or a long fallow with late planting, will lead to a missed harvest during the fallow year, and so may produce lower yield over a crop cycle than ‘ploughout-replant’ fields where the old crop is destroyed and the new crop replanted in the same year. Alternative methods of killing soldier fly between crop cycles may be useful to reduce the fallow period, allowing either early planting or ploughout-replanting and greater potential cane yield.

Unfortunately, none of the other methods tested here was shown to give a rapid kill of soldier fly larvae. Use of a rotary hoe and the combination of an insecticide with a lure crop were not effective. The break crops tested are likely to kill larvae by starvation and so will act slowly; brassicas were not shown to be toxic to larvae, and in any case their period of optimum growth period may not fit into a sugarcane rotation. Of all the options tested, use of the biocide metam-sodium is the most likely to give quick results. However, better application systems would need to be developed, presumably applying the chemical in large volumes of irrigation water. This is unlikely to be economic, and the side-effects on beneficial soil fauna could be catastrophic. In any case, such a procedure before planting would offer no protection against soldier flies that may migrate into fields, and the chemical cannot be applied into growing cane crops because of phytotoxicity.

Starving larvae during a fallow, while causing minimal disruption to the soil or beneficial soil fauna, currently seems the best way to minimise numbers of soldier fly in plant crops.

Figure 13: Fumus F-E75 on 11 January 2000

Figure 14: BQMulch™ on 11 January 2000

7.0 EXTENSION

The treatments included in long-term trials were developed at meetings with farmers held in southern and central districts in 1995. Long-term trials were subsequently included in a bus tour of Bingera growers in 1996.

A meeting of affected growers was held at Mackay in June 1997, to discuss further work and, in particular, to highlight initial success with alternative options for long fallows, ie sprayout of old ratoons and rotation with soybeans. Additional grower trials testing the sprayout and soybeans options for fallow management were established after the 1997 harvest.

Management procedures developed in the project were presented to growers at the BSES Information Meeting at Mackay in February 1998 ('Soldier fly in the Central Region – a manageable problem') and were outlined in subsequent media interviews for radio and television. A large article appeared in the Queensland Farmer (March 1998). A trial comparing different fallowing procedures for soldier fly management was included in a bus tour by growers at Mackay in April 1998. Posters on soldier fly management were prepared for both the BSES and CPPB field days at Mackay in April-May 1998 and at Bundaberg in April 1998.

Soldier fly workshops of about half-day duration were held for BSES and CPPB staff at Mackay on 7 July 1998 and Bundaberg on 14 July 1998. The Mackay meeting included staff from Proserpine to Sarina and the Bundaberg meeting included staff from Bundaberg to Nambour. Current progress was reviewed, recommendations for soldier fly management were examined, and the future program was discussed and additional activities planned.

A meeting with affected growers in the Burdekin was held in July 1998, focussing on new recommendations for soldier fly management.

Information on soldier fly management, promoting late planting with sprayout of old ratoons and reduced tillage, was presented at a large public meeting at Mackay in November 1999.

Two Pest Refresher Courses were held for BSES and CPPB advisory staff in 1999, at Bundaberg on 7-8 September and at Ayr on 7-8 December. The Bundaberg course was attended by staff from Bundaberg south, including New South Wales, and the Ayr course by staff from Sarina north. Soldier fly management was an important component of both courses, drawing heavily from results of BSS160.

Groups of farmers focussing on soldier fly management were formed under BSS225. Details of these groups and their meeting dates are:

Moreton:	5/8/99 and 26/8/99
Maryborough:	20/10/99, 22/5/2000 and 28/6/2000
Bingera:	2/12/99, 7/2/2000 and 29/6/2000
Finch Hatton:	22/11/99 and 31/3/2000.

These groups typically consist of 10-20 farmers plus the local BSES extension and CPPB officers. A summary of research results and management best-bets has been presented to each of these groups, drawing on results of BSS160.

A brochure has been prepared outlining best-bets for managing soldier flies, combining fallow and crop management. A copy is attached as Appendix I.

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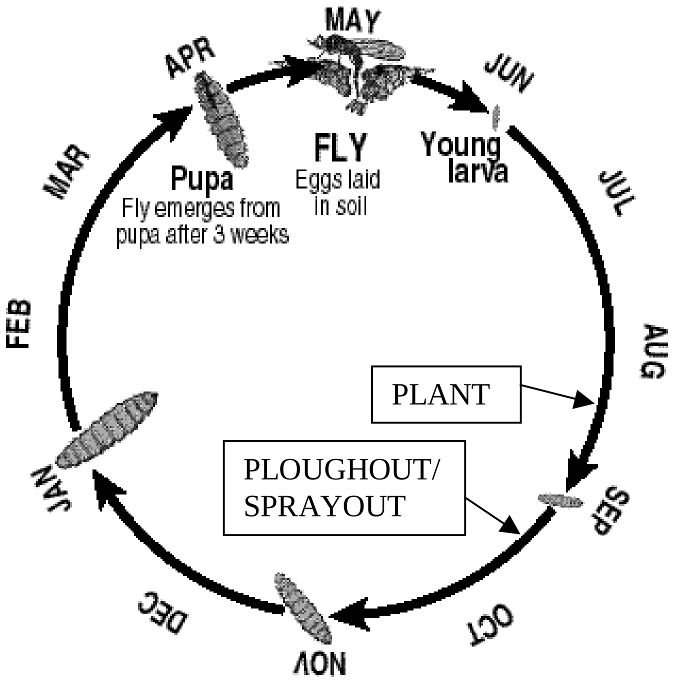
APPENDIX I

MANAGEMENT OPTIONS FOR CONTROL OF SOLDIER FLY

No insecticides are available for use against soldier fly.



Instead, you will need to adopt management practices that lower pest numbers while encouraging more natural enemies, and that allow the crop to tolerate some damage.

IDEAS BEHIND MANAGEMENT

- A major source of soldier fly populations in ratoons is larvae in the field at planting, giving rise to flies that breed and multiply each year.

- Grasses are the primary host plants of soldier fly larvae. Egg laying and larval survival are reduced if grass is absent.

- The build-up of soldier fly is slowed by a range of natural enemies, especially predators of pupae and, perhaps, eggs, and the fungal disease Metarhizium. These natural enemies can stabilise fly numbers in the long term.

- Natural enemies usually will be more plentiful in older ratoons, but they are harmed by cultivation when crops are replaced.

- The effect of soldier fly after harvest will be minimised if other conditions are favourable for rapid ratooning.

Therefore, you need to select management steps that will reduce numbers of larvae in the plant crop and cause least harm to existing natural enemies during crop replacement.

You also should manage the new crop in such a way as to get the best ratoons, first, to maximise yield, and second, to allow a longer ratooning cycle to give natural enemies time to build up.

MANAGEMENT STEPS

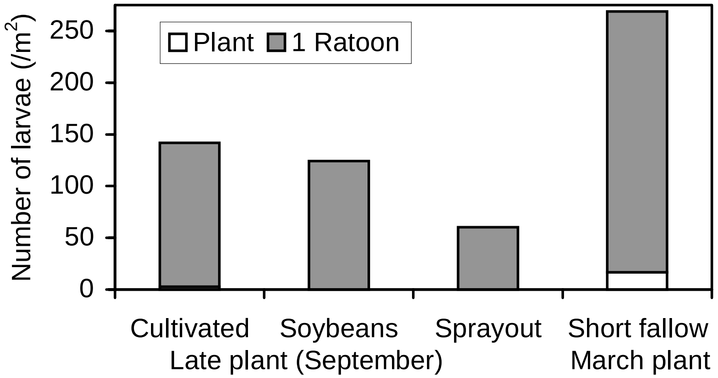
1. ***Take out affected blocks as early as possible in the harvest season.***

→ This will increase the length of the fallow period, giving fields a longer break from cane, and will destroy larval food while the larvae are still small and vulnerable.

2. ***Have a grass-free break from cane, eg a herbicide fallow after sprayout of the old ratoon under trash or a rotation with another non-grass crop such as soybeans.***

→ Larvae will starve as grasses are their natural food.

Average number of soldier fly after different fallows



Soybean and sprayout options for long fallow greatly reduced soldier fly in plant crops and may preserve natural enemies.

3. ***Plant late, after the flight period (ie after June).***

→ Flies are less likely to lay eggs if no cane or grass is present during the flight period.

4. ***Plant with minimum tillage following the herbicide fallow.***

→ By minimising soil disturbance, you are preserving natural predators in the soil.

5. ***Choose varieties that ratoon quickly.***

→ Soldier fly will cause less damage if ratoons come away more quickly.

6. ***Harvest plant and early ratoon crops when ratooning conditions are good.***

→ Cane ratoons more quickly and the effect of soldier fly will be less.

DO NOT: Ploughout-replant or plant early in autumn after a badly infested ratoon.

FOR MORE INFORMATION, CONTACT YOUR LOCAL BSES OFFICER OR CANE PROTECTION AND PRODUCTIVITY BOARD.

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