BUREAU OF SUGAR EXPERIMENT STATIONS

BRISBANE, AUSTRALIA

EFFECTS OF NATURAL ENEMIES ON SOLDIER FLY (Inopus rubriceps) POPULATIONS IN QUEENSLAND

by

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This report covers work undertaken while the author was at the University of Queensland on study leave from the New Zealand Ministry of Agriculture, to investigate possible methods of biological control of soldier fly.

Financial support for the surveys on which this report is based was provided by the Bureau of Sugar Experiment Stations.

The report has been circulated on a limited basis among BSES staff and other interested organisations.

Brisbane
November, 1983

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SUMMARY

Soldier fly pupae are attacked by three species of parasitic wasp and at least 10 species of predatory Coleoptera in both sugarcane and grassland in Queensland. Population densities of soldier fly may be regulated to a significant degree by the responses of predators (and possibly parasitoids) to increasing density.

The number of surviving pupae is the major factor in determining population change in soldier fly. Predation on eggs and larvae may occur but this apparently does little to influence population change. High mortality of eggs and early larval stages is evident whether predators are present or not.

Neurogalesus militis, the most common parasitoid of soldier fly in Queensland had little effect on population changes as it killed only male hosts. The parasitoid sp. A showed most promise as a biological control agent but it was least common and was probably competitively excluded by Neurogalesus species.

Metarhizium, the only disease isolated, killed a low proportion of larvae and pupae over the observation period.

The presence of persistent insecticide residues in canefield soils may at least partially exclude the natural enemy complex, and allow escape of soldier fly from natural regulation.

INTRODUCTION

The sugarcane soldier fly Inopus rubriceps (Macquart) is one of the more serious pests of sugarcane in Queensland. The fly is indigenous to eastern Australia and is found from Atherton and Innisfail in North Queensland, to Melbourne and Adelaide. The insect was accidentally introduced to New Zealand and California where serious damage to pastures, cereal crops and turf grasses has resulted. Damage to grasses other than sugarcane is rare in Australia.

Studies by Osborn (1974) in northern New South Wales sugarcane revealed two parasitoids (Neurogalesus militis Osb. Fort. & Holl. and N. 'inopodos' mss. name) which parasitised soldier fly pupae. Various vertebrates were also shown to feed on dispersing adult flies. The effect of these natural enemies on population dynamics was not determined. Work by Moller and Mungomery (1963) and Moller (1965) suggested that natural enemies were present in Queensland canefields, as low rates of dieldrin and lindane led to an increase in soldier fly densities. The specific predators, however, were not detected. In New Zealand grasslands, general predators such as Staphylinidae, Carabidae and Elateridae were shown to significantly influence densities of soldier fly (Robertson et al. 1981).

A study was initiated in 1981 to determine the role of natural enemies of soldier fly in south east Queensland. The objective of this work was to gain an understanding of soldier fly population dynamics in its native range. This paper presents information from a survey conducted to assess the degree of predation, parasitism and disease in soldier fly populations in Queensland. Intensive studies of natural enemies and population dynamics in south east Queensland are still in progress and will be reported in detail at a later date.

SAMPLING AND SURVEY METHODS

Techniques for accurately assessing the population size of soldier fly over defined areas have been devised for New Zealand grasslands, and these were adapted for use in Australian canefields and grasslands (Robertson, in press). Soil cores 7.61 cm diameter by 25 cm deep) were removed adjacent to emergent cane stalks. Soldier fly were extracted from the cores by sieving the organic material suspended from the mineral fraction of soil in flowing water. The efficiency of the extration varies from 90 to 100% for large larvae and pupae, and approximately 80% for smaller larvae sampled in spring. Eggs and the first two larval stages cannot be recovered efficiently by this method (Robertson, in press). Approximately 50% of all larvae and pupae occur within the central portion of cane stools, to a distance of 8 cm from emergent canes. Densities decline towards the inter-row space. Four cores taken from each of 10 randomly located stools (40 cores) give population estimates with as low as 10% standard error of the mean.

Surveys of soldier fly populations were extended to Mackay, Bundaberg and Maryborough in May-June 1982. These were timed to coincide with the latter part of the soldier fly flight period. Reports of localities with soldier fly were obtained from published accounts, records of BSES and Cane Pest and Disease Control Board officers, and specimens in insect collections. The locations were visited and sweepnet samples taken (between the hours of 9.00 a.m. and 12.00 noon where possible) to confirm the presence of flies. Spade samples of turf and soil surrounding cane stools were examined in the field to detect the presence of larvae and/or pupae. Where immature solider flies were found, 10-50 soil cores were removed and returned to Brisbane for extraction and counting of insects. Numbers of larvae, pupae (live and dead) and other arthropods in the soil were related to the number of cores taken, and converted to a standard density (number per square metre of soil surface) for comparison of sites. Although canefield samples did not include the inter-row space, absolute densities over whole fields can be obtained by multiplication with a conversion factor of 0.5 (Robertson, in press). This has not been used here, as virtually no soldier fly occur further than 30 cm from the emergent canes.

Subsequent visits were made to the same districts in spring 1982, autumn 1983 and spring 1983. The objective of the spring visits was to determine the success of the previous autumn emergence and breeding periods, with respect to the number of larvae recruited into the soil population. The autumn 1983 sampling extended the previous survey and continued the monitoring of previously sampled localities. Sampling was discontinued at several locations where ploughing or other management changes were implemented.

A history of each cane crop sampled was obtained from the grower where possible, particularly insecticide usage and age of crop. Samples were removed for insecticide residue testing from several sites. Twenty randomly located 2.5 cm diameter soil cores of 15 cm depth were bulked for each location, and a subsample analysed for BHC and dieldrin at BSES Brisbane. Areas with low population densities of soldier fly and high residue levels were not sampled further.

Pupae and larvae recovered from the soil were reared to detect diseases and parasitoids. The extraction technique allowed recovery of intact pupal cases to assess successful adult emergence (Robertson, in press). Pupae and larvae killed by parasitoids and predators could also be identified and classified by characteristic remains (Robertson, unpublished). At several sites with relatively high densities of soldier fly and predators/parasitoids, transects through a range of densities were taken. Stools 3-5 m apart were sampled by taking four to six cores from each and extracting soldier fly and remains. The variation in density between stools and subsequent levels of mortality could be used to indicate the responses of predators and parasitoids to soldier fly density, and hence likelihood of regulation.

LOCALITIES SAMPLED

1. Mackay district

Soldier fly adults were found in all canegrowing areas sampled, occasionally with I. flavus. The areas in which pupae and/or larvae were found in the soil included: Eimeo, Blacks Beach, Habana, Walkerston, Farleigh, Pleystowe, Marian, Mirani, Gargett, Pinnacle, Finch Hatton, Mackay, Bakers Creek, Alligator Creek, Koumala, Marian Creek, Ilbilbie and Carmila. Most of the canefield sites had a history of insecticide usage. The results of monitoring over the two-year period are given in Table 1.

The parasitoid N. militis was found in sweepnet samples at Carmila and Finch Hatton Gorge in autumn 1982, and was reared from pupae collected at Carmila that year. A second species, possibly synonomous with N. 'inopodos', was reared from pupae collected at Carmila in 1983. In addition, a specimen resembling this second species (called Neurogalesus sp.1 to differentiate it from N. militis) is in the University of Queensland Insect Collection with a label indicating collection from Finch Hatton Gorge. Specimens of 'inopodos' collected by Osborn (1974) have not been available for comparison.

Table 1 : Sites monitored for soldier fly and predators and parasitoids

Locality	Date	Average No. m^{-2} Soldier fly	Predators	% pupae killed by predators	Parasitoids	% pupae parasitized
Carmila cane	1982	1800 pupae 1160 larvae	*Philonthus* sp., *Conoderus* spp.	37	*N. militis*	20
	1983	840 pupae 1200 larvae		24	*N. militis* & few *N.* sp.1.	20
Finch Hatton gorge cane	1982	20 pupae 28 larvae	*T. chalcopterus*, *Philonthus* sp., *Conoderus* spp., *Gnathaphanus* sp.	N.A.	*N. militis*	N.A.
(ploughed - replanted)	1983	20 pupae 0 larvae		N.A.	*N. militis*	N.A.
Finch Hatton grass	1982	20 pupae 35 larvae	*T. chalcopterus* *Anisotarsus* sp. *Conoderus* spp.	N.A.	*N. militis*	N.A.
	1983	20 pupae 0 larvae		N.A.	*N. militis*	N.A.
Burnett R. cane	1982	3100 pupae 2000 larvae	*T. chalcopterus* *Philonthus* sp.	51	None detected	0
(second site)	1983	320 pupae 2500 larvae	None detected	0	None detected	0
Burnett R. grass	1982	80 pupae 100 larvae	*T. chalcopterus* *Gnathaphanus* sp. *Conoderus* spp.	33	None detected	0
	1983	0 pupae 0 larvae		N.A.	None detected	0
Wallaville grass	1982	160 pupae 80 larvae	*T. chalcopterus* *Anisotarsus* sp. *Philonthus* sp. *Conoderus* spp.	27	None detected	0
	1983	60 pupae 220 larvae		33	None detected	0

..... cont.

Table 1 : continued

Locality	Date	Average No.m^{-2} Soldier fly	Predators	% pupae killed by predators	Parasitoids	% pupae parasitized
Walkers Pt. cane	1982	– pupae	*T. chalcopterus*	N.A.	None detected	0
		5570 larvae	*Conoderus* spp.			
(second site)	1983	330 pupae	None detected	0	None detected	0
		4340 larvae				
Walkers Pt. grass	1982	70 pupae	*T. chalcopterus*	33	None detected	0
		100 larvae	*Gnathaphanus* sp.			
	1983	0 pupae	*Conoderus* spp.	N.A.	None detected	0
		60 larvae				
Petrie Ck. cane	1983	510 pupae	*T. chalcopterus*	22	*N. militis*, &	46
		520 larvae	*Anisotarusus* sp., *Conoderus* spp.		few *N.* sp.1	
Petrie Ck. grass	1982	130 pupae	*T. chalcopterus*	17	*N. militis*	33
		810 larvae	*P. oodiformis*			
	1983	400 pupae	*Conoderus* spp.	33	*N. militis*	10
		250 larvae				
Yandina cane	1982	580 pupae	*T. chalcopterus*	64	None detected	0
		360 larvae	*Anisotarsus* spp.			
	1983	360 pupae	*P. oodiformis*	49	None detected	0
		200 larvae	*Gnathaphanus* spp. *Conoderus* spp.			
Yandina grass	1982	480 pupae	*T. chalcopterus*	77	None detected	0
		370 larvae	*Anisotarsus* sp.			
	1983	200 pupae	*Gnathaphanus* spp.	44	None detected	0
		390 larvae	*Conoderus* spp.			

..... cont.

Table 1 : continued

Locality	Date	Average No.m^{-2} Soldier fly	Predators	% pupae killed by predators	Parasitoids	% pupae parasitized
Yatala cane	1981	400 pupae 700 larvae	*T. chalcopterus* *Gnathaphanus* sp. *Conoderus* spp.	4	Unid. sp.A.	51
(second site)	1982	50 pupae 430 larvae		12	*N. militis* & few unid. sp.A.	36
	1983	330 pupae 2000 larvae		11	*N. militis*	20
Yatala grass	1982	500 pupae 160 larvae	*T. chalcopterus* *Gnathaphanus* spp. *Conoderus* spp.	80	*N. militis*	10
	1983	90 pupae 160 larvae		50	*N. militis*	13
Coomera cane	1982	850 pupae 600 larvae	*T. chalcopterus* *Anisotarsus* spp. *Gnathaphanus* spp. *Conoderus* spp.	70	*N.* sp.1	1.5
	1983	360 pupae 200 larvae		34	*N.* sp.1	17
Coomera grass	1982	460 pupae 950 larvae	*T. chalcopterus* *Anisotarsus* sp.	82	*N.* sp.1	14
	1983	190 pupae 50 larvae		71	*N.* sp.1	8

N.B. Larval densities corrected for inefficient extraction of early stage larvae.

N.A. - not analysed due to low densities of soldier fly.

The presence of an apparently undescribed stratiomyid, possibly related to Boreiodes, complicated the sampling at Carmila. Pupae were not distinguished from I. rubriceps in 1982. Females are entirely wingless. The species dominated I. rubriceps in the ratio 2:1 in autumn 1983 in sugarcane. Neurogalesus militis parasitised the undescribed species as well as I. rubriceps and an ichneumonid wasp (Megastylus sp.) emerged from a pupa in autumn 1983. I. flavus did not occur at any of the sites monitored over the two-year period.

2. Bundaberg district

Sweepnet and spade samples were examined at Childers, Isis (various), Gin Gin, Morganville, Wallaville, South Kolan, Bundaberg, The Hummock and Bargara. Flies were invariably present although pupae and larvae were not always detected in the soil. No parasitoids were found in sweepnet samples, nor were they reared from pupae collected in the district. I. rubriceps was the only stratiomyid collected from cane. The sites monitored over the two-year period are detailed in Table 1.

3. Maryborough district

Soldier fly adults were common in the Walkers Point area and near Saltwater Creek on the opposite bank of the Mary River. None were found in the Bauple district, despite records indicating their presence there. High densities of larvae and pupae were found at the lower part of Walkers Point (Table 1). No parasitoids were found in this district, although predators were common, particularly in grassland with soldier fly.

4. Nambour district

This area was regularly visited from 1981 and a previous survey (Hitchcock, 1971 unpublished) disclosed the wide distribution of soldier fly.

The parasitoid N. militis was found in cane and grassland along Petrie Creek between Nambour and Bli Bli. Neurogalesus sp.1 was reared from pupae collected in cane near Bli Bli in autumn 1983. One wasp of this species was taken in a sweepnet sample with I. rubriceps over kikuyu near Maleny in autumn 1982. Other specimens have been collected from soldier fly pupae in Brisbane grass.

5. Rocky Point district

Soldier fly populations have been monitored at Coomera and Yatala since 1981. Most of the soils in this canegrowing area are unsuitable for soldier fly, apart from the alluvial sands and silts. Neurogalesus sp.1 has been present at Coomera since 1981, and N. militis at Yatala since autumn 1982. A third species of the same family (Diapriidae) was present in large numbers in pupae under cane at Yatala in 1981 and early 1982, but has not been found in 1983. This apparently undescribed genus and species (here called sp.A) differs from Neurogalesus in its small size and the production of multiple wasps from each host pupa.

PARASITOIDS OF SOLDIER FLY

N. militis was the most widespread of the three species of parasitic wasp recovered from pupae. It was present from Finch Hatton Gorge in the north to Yatala near Beenleigh, and was originally described from near Grafton, New South Wales. It occurred in considerable numbers with relatively high densities of soldier fly pupae at several locations (Table 1). This wasp parasitised only small soldier fly hosts entirely within the size range of male pupae (Figure 1). The mechanism which determines this behaviour is unknown, although the size of the wasp indicates that male pupae hosts are an optimum size to accommodate development.

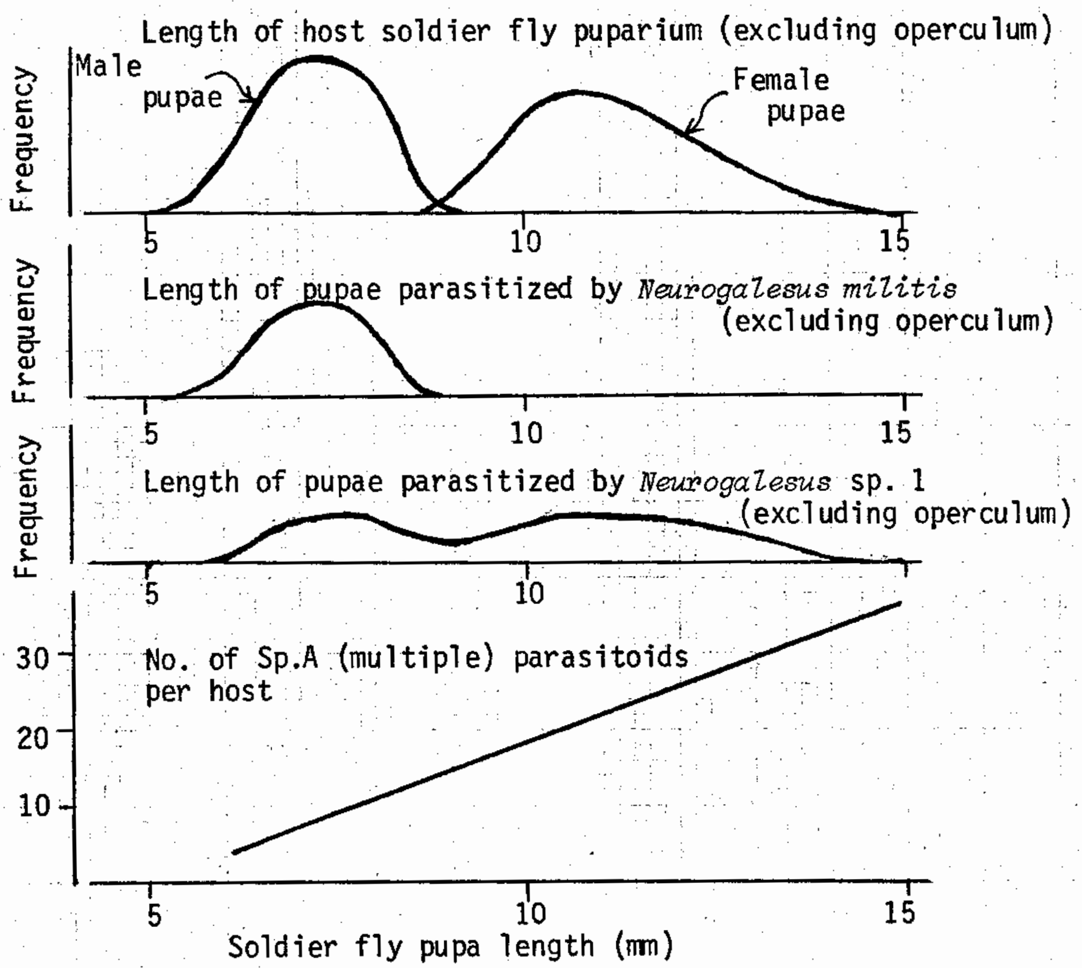

Figure 1: Relationship between three species of diapriid parasitoid and host soldier fly pupa length

Strong indications of density-dependent relationships between level of parasitism by N. militis and pupal numbers were revealed (Figure 2). Nevertheless, monitoring of populations at Yatala particularly, suggested that N. militis did not reduce the size of subsequent larval populations (Table 1). Sufficient males presumably survived to allow successful breeding by females.

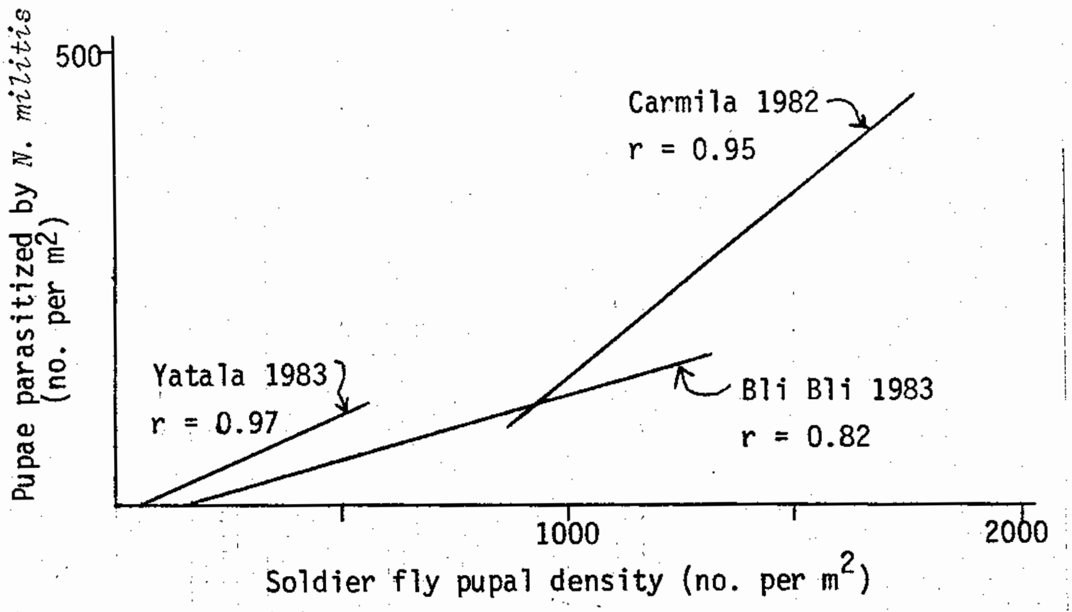

Figure 2: Density dependent parasitism of soldier fly pupae by N. militis

Neurogalesus sp.1 was generally less common that N. militis although it was confirmed as far north at Carmila as well as Nambour and Rocky Point. Females of the wasp are considerably larger than N. militis and parasitise both male and female pupae of I. rubriceps (Figure 1). Despite the low densities of hosts and parasitoids at Coomera, intensive sampling suggested a density-dependent relationship which could lead to regulation or control of soldier fly density. A proportion of Neurogalesus sp.1 over-winter in the host puparium to emerge October-November. This may make the species vulnerable to mortality during harvesting and ratoon cultivation. The species was more common in grassland and standover cane than harvested crops at Coomera in 1983.

The underscribed multiple parasitoid from Yatala parasitised the entire size range of host pupae, with the number of wasps emerging dependent on the pupa size. As few as four wasps emerged from small male pupae, while up to 38 wasps were recorded in large female pupae (Figure 1). This wasp was apparently replaced by N. militis during autumn 1983 at Yatala, and has not been recorded there or elsewhere since that time. A strong density-dependent relationship between soldier fly pupal numbers and level of parasitism was shown for this species in 1981, indicating its potential for biological control in the absence of competing Neurogalesus species (Figure 3).

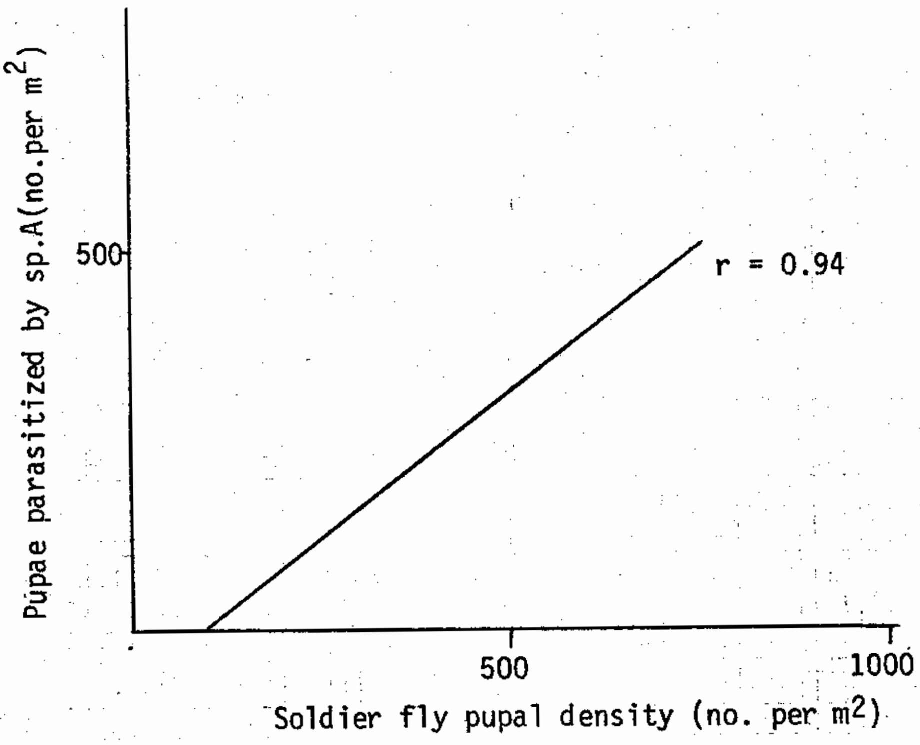

Figure 3: Density dependent parasitism of soldier fly pupae in Yatala sugarcane. (Unidentified diapriid sp. A)

No parasitoids of soldier fly were detected in the Bundaberg and Maryborough districts. These two areas are the driest of the canegrowing regions in Queensland (King et al. 1965). Neurogalesus at least is apparently confined to wet areas (Dodd 1915).

PREDATORS OF SOLDIER FLY

The predators most commonly encountered attacking soldier fly are pupal predators. Larvae are relatively invulnerable to predation. Recent work (Robertson, unpublished) has shown that the most voracious predator of soldier fly pupae is the staphylinid Thyreocephalus chalcopterus (Erichs.). This species has been found in cane and grasslands in all sugar growing regions from Mackay to Grafton. Although never abundant (usually less than 20 per m^2) it can increase its feeding rate as soldier fly density increases, in a way similar to that of T. orthodoxus in New Zealand grasslands (Robertson et al. 1981). T. chalcopterus was recorded at every site monitored except Carmila. Immature staphylinids as well as adults feed on pupae and larvae of soldier fly and can kill up to 1.5 pupae per day.

A complex of carabid beetles also feed on pupae in the upper layers of soil in cane and grass. At least two species of Anisotarsus are common from Coomera to Mackay with densities of up to 100 per m^2 in sugarcane. These species have lower individual rates of consumption than staphylinids (0.2 - 0.4 pupae per day) but they are capable of rapidly increasing their own densities by breeding responses. Other carabids which occur with soldier fly and consume pupae include Gnathaphanus pulcher Dej., G. picipes Macl., G. multipunctatus Macl. and Prosopogmus oodiformis (Macl.). Not all species were found at all sites, although the sampling techniques were not specifically designed for predatory beetles.

Wireworms (Elateridae) of the genus Conoderus were widespread throughout coastal Queensland, and found at every locality sampled. Although omnivorous, this group are active predators (see Robertson et al. 1981) and consume up to 0.7 larvae or pupae per day. Wireworm densities seldom exceeded 40 per m^2. Several species were present in cane and grassland but taxonomic difficulties precluded identification of species.

Analyses of density relationships suggested that levels of predation generally increased with increasing densities of soldier fly pupae. The results of four transects in sugarcane are shown in Figure 4. Total predation was analysed, as the contribution of all individual predatory species could not be assessed in most cases.

Numerous species including ants and carabids have been determined as predators of eggs, but none apparently influence soldier fly population dynamics. Pupal predation is the main factor determining the size of subsequent populations of soldier fly, as suggested by a significant correlation between pupal survival (to adult flies) and number of larvae recruited into the soil ($r = 0.71$, $P < 0.01$). A high mortality (80-95%) of eggs and early stage larvae was apparent even in the absence of predators (Robertson, unpublished).

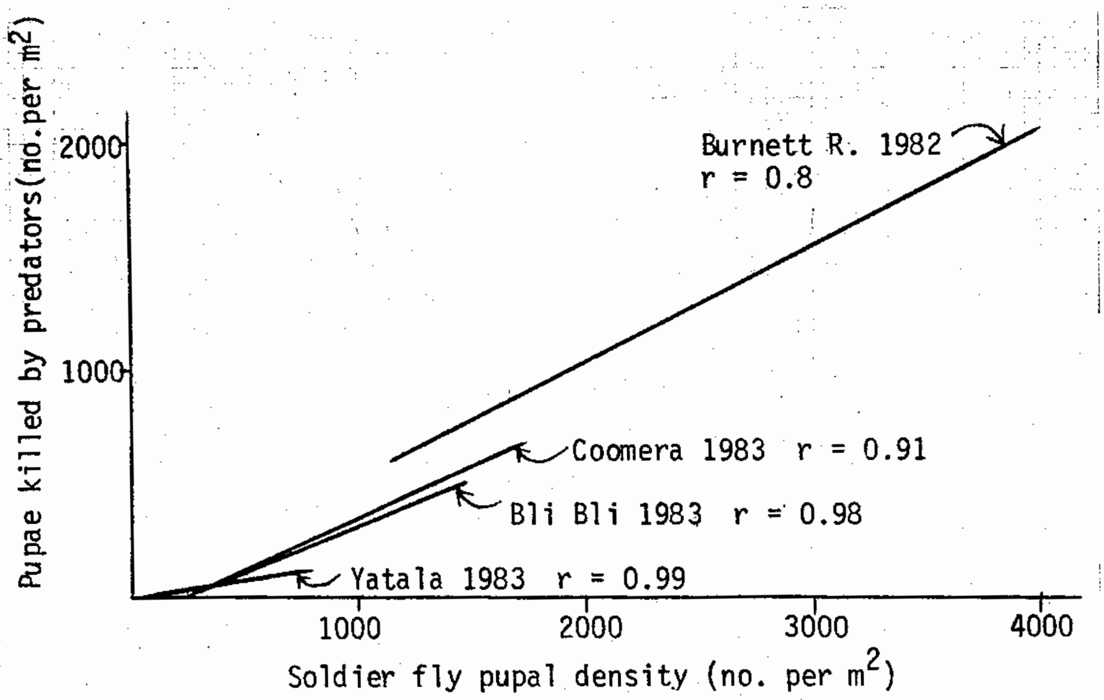

Figure 4: Density dependent predation of soldier fly pupae in cane

DISEASES OF SOLDIER FLY

Despite regular screening, the only pathogenic disease isolated was Metarhizium anisopliae var. anisopliae (Metsch.). Two strains of this were seen, one which produces a synnematal outgrowth of hyphae up to 1 cm from the cadaver and the more common form with spore bodies forming directly on the cuticle surface. Throughout this study, Metarhizium incidence was below 5% at any one time. Both larvae and pupae of soldier fly were affected at all locations, and the disease occurred in all seasons.

POSSIBILITY OF NATURAL CONTROL IN SUGARCANE

All predatory and parasitic species which have been shown to attack soldier fly occur in sugarcane as well as grassland. High levels of predation and parasitism occur in soldier fly populations in cane despite management practices such as fire, harvesting and cultivation. The generally low densities of soldier fly in grasslands, despite potentially favourable host plants (e.g. kikuyu) and suitable soil conditions imply regulation in that habitat. The major difference between grassland and adjoining canefields at several localities, notably Walkers Point, Maryborough and Burnett River, Bundaberg, was the relatively depauperate fauna of predatory beetles in the cane. This was undoubtably due to the use of organochlorine insecticides in the cane, particularly dieldrin (Table 2). Pest resurgence following the suppression of predators by dieldrin or lindane has been demonstrated in south east Queensland (Robertson, unpublished) and in grassland in New Zealand (Robertson et al. 1981). Pupal survival and subsequent larval recruitment was high under low rates of dieldrin.

Table 2 : Insecticide residues detected in cane-field soils from monitored sites. (parts per million, oven-dry soil).

Locality	Date	BHC				Dieldrin
		α-	β-	γ-	δ-	(HEOD.)
Yandina	1982	0.02	-	-	-	0.05
Finch Hatton gorge	1982	0.05	0.12	0.03	-	-
Carmila	1982	1.05	1.46	0.46	0.06	-
Walkers Point	1982	0.36	0.94	0.15	0.25	1.3
Walkers Point (Site 2)	1983	-	-	-	-	0.5
Burnett River (Site 2)	1983	-	-	-	-	0.4

The natural tolerance of soldier fly to dieldrin is highlighted by its ability to rapidly prolifierate when residues decline to 1.5 - 2.0 p.p.m. HEOD. These rates however, exclude predatory beetles and parasitoids. The staphylinid T. chalcopterus may be one of the first species to re-establish in treated areas (see Walkers Point, Tables 1 & 2). Parasitoids may have a higher tolerance of BHC than dieldrin, as N. militis was found with 0.5 p.p.m. γ-BHC at Carmila (Table 2). Sites sampled at Yatala and Coomera have no history of insecticide use, have a varied complex of predators and parasitoids and relatively low densities of soldier fly.

No economic evaluations of soldier fly attack in cane were attempted in this study, but casual observations suggested that larval densities of 2 000 - 3 000 per m^2 could prevent successful ratooning of the crop

ACKNOWLEDGEMENTS

The surveys to Mackay, Bundaberg and Maryborough were made possible by a grant from the Bureau of Sugar Experiment Stations. I wish to thank staff of BSES for considerable assistance throughout the study, particularly Mr B.D.A. Stickley (for insecticide residue analyses) and Messrs B.E. Hitchcock, R.M. Bull, L.K. Izatt and A.I. Linedale. The study was made while in receipt of a postgraduate fellowship from the New Zealand National Research Advisory Council.

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Appendix : Description of survey/monitoring sites

Locality	Grower	Soil Type	Description of site
Carmila	Mr L.Major	Stony silt-sand	Terrace below and to north of Carmila school.
Finch Hatton gorge	Mr G.N.Ware	Stony silt-sand	Adjoining Finch Hatton creek, downstream from ford crossing.
Burnett R.	Mr R.Schmitt (Bonna Rd.)	Silty-sand	Lower terrace adjacent Burnett R. North from buildings.
Wallaville	Mr D.Maugham	Sandy clay loam	Adjacent to and south-east of Wallaville school.
Walkers Pt.	Mr K.Burt	Silty-sand	Adjacent Mary R. on west side of end Walkers Pt. road
Petrie Ck. (cane)	Mr R.Taylor (Petrie Ck.Rd.)	Sandy-silt	Adjacent Petrie Ck. North-east from buildings.
Petrie Ck. (grass)	Moreton Mill block	Silty-sand	Adjacent Petrie Ck. Road, south-west from junction Panorama Rd.
Yandina (cane)	Mr R.Garrett (Coolum Rd.)	Volcanic complex (friable clay)	Immediately east of house and south side of Coolum Rd.
Yandina (grass)	Mr W.Davison (North Arm)	Volcanic loam (friable clay)	Near summit of hill to south-west of buildings.
Yatala	Mr N.Brauer	Silty-sand	Adjacent to Albert R. immediately downstream from Pacific Hwy. Bridge.
Coomera	Mr H.Beattie	Sandy-silt	Adjacent to Coomera R. at downstream end of property.