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**FINAL REPORT - SRDC PROJECT BS77S
STUDIES ON THE BIOLOGY OF NEGATORIA AND
CHILDERS CANEGRUBS AS A BASIS FOR
DEVELOPMENT OF IMPROVED CONTROLS
by
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SUMMARY

The biology of the two most important species of canegrubs affecting sugarcane in southern Queensland, Childers canegrub (*Antitrogus parvulus* Britton) and negatoria canegrub (*Lepidiota negatoria* Blackburn) was studied during a 5-year period. Rearing methods were developed and the phenology of each species was determined. Data were collected on development, mortality and reproduction in laboratory and field trials; these data were summarised as a computer model for each species. Various management scenarios were simulated using the computer models. Short crop-length (3-4 years) and consistent application of control measures (insecticide and plough-out) could drive populations of canegrubs to extinction after 5-8 generations. Further field data are needed to validate many of the results of the model.

1.0 BACKGROUND

Canegrubs are the major insect pests of the Australian sugar industry. They cost the industry \$8-10 million a year in lost production and insecticide, but their impact could be much higher if suitable insecticides or alternative controls were not effective or not available. Grubs are currently controlled with suSCon® Blue applied at or soon after planting, or with Mocap® 10G or Rugby® 100G applied to ratoon crops.

In southern Queensland and northern New South Wales, ten species damage sugarcane. Childers canegrub, *Antitrogus parvulus* Britton, and negatoria canegrub, *Lepidiota negatoria* Blackburn, are the most important species. They differ in life cycles, seasonal history, soil-type preferences, and susceptibility to insecticides. Southern canegrubs were first studied in the late 1920s, but only broad outlines of the biology of any of the species are available (summarised in Allsopp *et al* 1993 and Agnew 1997). There are few data on fecundity, survival of immature stages and effects of natural enemies.

Before alternative management strategies can be designed and rationally evaluated (especially within an IPM framework), details of the target species' field survival and biology are needed. Temperature, soil moisture and natural enemies are the main factors affecting population growth and development of soil-dwelling insects. Incorporation of these data into a population dynamics model would allow management strategies to be simulated and evaluated.

2.0 OBJECTIVES

- Measure the effects of age and fecundity of adults, and of soil type, soil moisture and temperature on the potential and realised fecundity of negatoria and Childers canegrubs;
- Measure the effects of temperature, soil moisture and soil type on the development and survival of all stages of negatoria and Childers canegrubs;
- Determine and measure the effects of natural enemies and management inputs which restrain the population growth of negatoria and Childers canegrubs;
- Develop a life table and adapt an existing generic insect population-dynamics model to model the population dynamics of negatoria and Childers canegrubs.

3.0 OUTCOMES

- Adults of *A. parvulus* and *L. negatoria* each lay a single batch of eggs generally within 14 days of mating. Fecundity averages 17-18 eggs for both species but varies with the size of the adult. Adult size is less variable for *L. negatoria* than for *A. parvulus*. The largest adults of *A. parvulus* were found at Cordalba, an area with historically high levels of canegrub damage.
- Rainfall and the associated increase in soil moisture were the major predictors of emergence by adults of *A. parvulus* and *L. negatoria*.
- Multiple linear regression models were constructed to describe emergence and flight by *L. negatoria* in each of the five summers from 1992/93 to 1996/97. Models included the variables rainfall, wind-speed, barometric pressure and minimum air temperature. The prediction of the numbers of mating pairs was 10-66%.
- Temperature significantly affects the survival of eggs, some larval stages and pupae of both species. Third instars of both species, which had formed cells in which to pupate, did not survive when average hourly temperatures exceeded 24-26°C.
- Decomposing vegetable matter was an inadequate diet for first instars, contrary to accepted opinion. Development from egg to adult was successful when larvae were provided with grass seedlings or setts of sugarcane with sett roots.
- Development rate was temperature-dependent for all immature stages except for the third instar. Development rate of larvae varied according to diet, being more rapid on grass seedlings than on sugarcane. Development during the third instar of both species is poorly understood. A feeding stage (temperature-dependent) is followed by an extended late non-feeding stage in which larvae form a cell relatively deep in the soil profile in preparation to pupate.
- Females of *A. parvulus* preferred to lay eggs in soil with moisture levels near field capacity, while females of *L. negatoria* did not discriminate between soil of different moisture levels above wilting point. Survival of eggs of both species was poor in soil below wilting point but consistently high in soil above wilting point.
- Natural enemies (other than diseases) were found to occur at very low levels in the field and probably play an insignificant role in the population dynamics of *A. parvulus* and *L. negatoria*. In sampling studies, numbers of third instars of both species declined by 50-95% during summer. This mortality may be directly or indirectly associated with hot summer temperatures. Plough-out and fallow have a significant impact on populations of *L. noxia* Britton and probably on populations of *A. parvulus* and *L. negatoria*.
- The phenology of *A. parvulus* and *L. negatoria* and the seasonal soil distribution of each stage were determined. Third-instar larvae of each species do not overwinter deep in the soil profile as previously thought.

- Models of the life-history of each species were constructed using the generic model DYMEX. Changes in the relative abundance of each species were simulated under natural conditions and after various management strategies were imposed. Populations could be depressed or driven to extinction after 5-8 generations if crop life was kept to 3-4 years and the management methods of knockdown or controlled-release insecticide were applied in each crop and ploughout occurred at the end of the crop.

4.0 RESEARCH METHODOLOGY, RESULTS AND DISCUSSION

The following summarises material to be presented in D P Logan's PhD thesis. A copy of the thesis will be sent to SRDC on completion of the degree.

A life-system approach (Hughes *et al* 1984) was adopted to study the biology of *A. parvulus* and *L. negatoria*. Data were collected on three processes involved in life-systems, development, mortality and reproduction; and summarised as a computer model for each species.

As no previous attempts had been made to rear either species from egg stage, methods of rearing *A. parvulus* and *L. negatoria* were developed to facilitate laboratory studies of development rate and survival. First-instar larvae survived and developed well when provided with grass seedlings. Diets such as composted grass or sections of cane stem led to poor survival and development of first instars. Larvae were also reared successfully to the adult stage when they were provided with single-eye setts of sugarcane with sett roots at least 15-20 mm long. Treating one-eye setts with fungicide to prevent pineapple disease had no effect on the survival of larvae. Laboratory rearing had a negative effect on the ultimate size of canegrubs. Adult beetles of *A. parvulus* and *L. negatoria*, that were collected in the field, were larger and more uniform in size than those derived from larvae collected from the same sites in the field, but reared in the laboratory for over 200 days.

The phenology of each species was studied by field sampling to determine how behaviour, such as overwintering deep in the soil profile, was likely to affect processes involved in population changes. Studies were conducted in damaged and in most cases, untreated blocks of sugarcane (*A. parvulus*, 3 sites; *L. negatoria*, 2 sites). Sites were visited at intervals of 3-5 weeks from spring for 12 months.

The phenology of both species is very similar. In the first year of their development, larvae (second and young third instars) did not overwinter deep in the soil profile as previously thought; instead larvae remained near the stool until feeding was completed in the third instar. Larvae then began to move deeper in the soil profile to form pupal cells. Pupation occurred from September and adults were ready to emerge from November onwards. Eggs of *A. parvulus* were laid deeper in the soil (300-500 mm) than those of *L. negatoria* (125-200 mm). The depth of pupation of both species varied with site. Median depths of pupation by *A. parvulus* were 320-420 mm; median depths of pupation by *L. negatoria* were 200-300 mm. The median depth of second and third instars of *A. parvulus* in the field was not related to soil moisture. In a pot trial, the vertical distribution of all larval instars of *A. parvulus* and *L. negatoria* did not change as soil dried out. Two allochronic populations (differing in age by 12 months) often occur in the same field. Separating third instars of *A. parvulus* belonging to each population is difficult because of their similarity in appearance; those of *L. negatoria* are more readily separated. At

sampling sites, allochronic populations of *A. parvulus* differed in size by a factor of about two while those of *L. negatoria* differed by much greater factors.

Development of both species was studied by determining the rate of development of each immature stage under variable temperature regimes. Studies were conducted under laboratory conditions, as direct observation of the same individuals is not possible in the field. In addition field studies of soil insects generally require destructive sampling of the habitat that can also destroy the soil insects themselves. The program DEVAR (Dallwitz and Higgins 1992) was used to estimate the parameters of two functions (linear above threshold and modified Stinner) describing an instantaneous temperature-development rate relationship. Data were collected for all immature stages and for ovarian development in *A. parvulus*. Development rates for larvae provided with grass seedlings were much higher than for larvae provided with cane roots. Differences in development rate between larvae fed different diets (grass or cane) were greatest for first instars. Development of third instars of both *A. parvulus* and *L. negatoria* was poorly related to temperature. Development during the third instar was investigated further by determining growth curves and by studying various factors observed to influence the timing of pupation in other scarabs (chilling, size).

Growth curves of third instars of *A. parvulus* and *L. negatoria* followed a similar pattern. There was an initial period during which larvae gained weight rapidly and a second period during which larvae lost weight gradually until pupation. Larvae formed cells about halfway through the period of gradual weight loss. Development was strongly temperature-related in the initial period of rapid weight gain, was weakly temperature-related in the period of gradual weight loss until cell formation and was not related to temperature in the period between cell formation and pupation. Development was found to be temperature-related for third instars collected from pupal cells in the field in winter. Mortality was strongly temperature-related for larvae in cells; maximum temperatures greater than 26°C killed all larvae. Chilling third-instar larvae resulted in early pupation relative to unchilled larvae. The largest larvae were found to pupate earliest. Development in third instars and the timing of pupation are complex and cannot be modelled on a mechanistic basis. There may be a period of diapause when third instars occur in cells in autumn. Further work is necessary to understand the biology of the third instar.

The effects of two mortality factors, soil moisture and soil temperature, on immature stages of *A. parvulus* and *L. negatoria* were determined in laboratory studies. Survival of eggs of *A. parvulus* and *L. negatoria* was poor in soil below wilting point, but consistently high in soil moisture at or greater than wilting point. Survival of early instars of *A. parvulus* and *L. negatoria* was best in soil just above wilting point. Temperature had significant effects on the survival of eggs, larvae and pupae. Pupae and eggs of both species had consistently high survival in all temperature regimes, while survival of third instars was relatively low. Temperature optima for survival of immature stages of both species lie in the range 20-26°C.

Emergence and flight of *A. parvulus* and *L. negatoria* were studied in the field with light-traps and emergence traps. Counts of mating pairs of *L. negatoria* were made at one site each evening throughout the flight period during the five summers from 1992/93 to 1996/97. Survival of adults and the effect of access to food on oviposition by *L. negatoria*

were studied in large cages. Potential and actual fecundities were studied by dissection and in laboratory and field trials.

Adults of *L. negatoria* first appear in flight about 15 minutes after sunset while those of *A. parvulus* emerge about 30 minutes after sunset. In both species, swarming and subsequent mating occurs during the 30 minutes after flight has begun. Mating by *A. parvulus* occurs on the ground or at ground level near the site of female emergence, while *L. negatoria* mate on low hanging branches, tree-trunks, shrubs, fences and sugarcane plants probably within 150 m of emergence sites. Emergence by both species is strongly associated with rainfall and an increase in soil moisture. Light traps captured mainly males of *A. parvulus* (sex ratio male:female 0.993:0.007) and mainly females of *L. negatoria* (sex ratio male:female 0.42:0.58). Numbers of beetles of both species captured by light traps were higher in summers beginning in even-numbered years than in alternate years.

Females of *A. parvulus* emerge with ovaries that are fully-developed, while those of *L. negatoria* emerge with ovaries at variable stages of development. Feeding on leaves of mango, a common aggregation plant on farms in the Bundaberg region, did not affect longevity or fecundity of *L. negatoria*. Fecundity in *A. parvulus* was influenced by the size of females, which varies from site to site and year to year. The largest females were found at Cordalba, an area that has historically had significant pest problems with *A. parvulus*.

The influence of various meteorological factors on the flight of *L. negatoria* was determined to enable emergence and flight to be predicted. Two multiple linear regression models were constructed, based on data for a range of meteorological variables and numbers of mating pairs of *L. negatoria* in two summers. Variables included in the models were rainfall, wind-speed, barometric pressure and minimum air temperature. Correlation coefficients for predictions of the number of mating pairs in each summer of the study period ranged from 0.1-0.66. All regressions were highly significant.

As soil moisture is an important factor determining the distribution and persistence of scarabs, the effect of soil moisture on oviposition by each species was studied in laboratory trials. Under choice conditions, females of *A. parvulus* discriminated between soil of different moisture levels. Most eggs were laid in soil near field capacity. Very few or no eggs were laid in soil at wilting point or drier than wilting point. Under choice conditions, females of *L. negatoria* avoided laying eggs in soil below wilting point but did not discriminate between soil moistures above wilting point.

The modelling tool DYMEX was used to construct computer models of the lifecycles of *A. parvulus* and *L. negatoria*. These DYMEX models were used to simulate long-term population change (up to 9 generations) in *A. parvulus* and *L. negatoria* in sugarcane fields. Parameters of functions describing the processes of mortality, development, transfer from stage to stage and reproduction were based on experimental data. Where experimental data were not available, best-guess estimates were used. Simulations were based on one of two meteorological databases (Bundaberg and Maryborough) which included the variables rainfall and daily maximum and minimum soil temperatures at 200 mm deep. Temperatures were used to simulate development and temperature-dependent mortality.

The models constructed for *A. parvulus* and *L. negatoria* each consisted of eight life-stages: egg, four larval stages, pupa and two adult stages. The third instar of both species was divided into two stages, a feeding and a non-feeding stage to enable differences in mortality due to temperature, cultivation/plough-out and insecticide to be modelled. The adult stage of *A. parvulus* was divided into pre- and post emergent stages, and emergence by adults was linked to rainfall. The adult stage of *L. negatoria* was divided into nulliparous and parous stages; emergence was not directly simulated but was assumed to occur during the nulliparous stage. Pupation for both species was arbitrarily fixed to day 280 of the year. Pupation effectively synchronised the life-cycle of *L. negatoria* and both pupation and rainfall-linked emergence synchronised the life-cycle of *A. parvulus*.

The models were verified using laboratory rearing data. A limited validation of the models was attempted using data for the transition from first to second instar for one site for each species. Parameters for the rate of moulting had to be adjusted to accommodate the longer than predicted transition period from first to second instar.

Natural mortality in field populations is less well understood than development. As much mortality was linked with temperature, the use of two meteorological databases to simulate changes in the abundance of *A. parvulus* and *L. negatoria* enabled a range of natural mortality to be simulated. The models were used to simulate the effect of various management strategies (controlled-release insecticide, knockdown insecticide, plough-out, fallow, no-till cultivation) over periods of 5-9 consecutive generations. Mortality due to management practices was superimposed on natural mortality. Crop length was varied to assess the effect of the frequency of plough-out on the abundance of canegrubs during an 18-year period. The effects of controlled-release and knockdown insecticides on population change were also simulated. Populations could be driven to extinction after 5-8 generations if crop life was kept to three years or less and the management methods of knockdown or controlled-release insecticide were applied in each crop and plough-out occurred at the end of the crop. The effect of plough-out on numbers of canegrubs in the subsequent crop depended on whether it occurred in the first or second year of the canegrub life-cycle. Plough-out and replant in the spring of the first year, when larvae were feeding, had a significant influence on canegrub numbers in the subsequent generation; there was no effect if plough-out occurred in the second year of the canegrub life-cycle, when larvae were in pupal cells below plough depth.

Mortality due to predation and parasitism was estimated during field studies of the phenology of each species. Insect predators and parasites occurred at very low densities probably precluding any significant effect on the abundance of canegrubs.

5.0 RECOMMENDATIONS

The lack of a distinct overwintering behaviour in both *A. parvulus* and *L. negatoria* means that plough-out and knockdown insecticide will be affective in killing larvae in the earliest harvested crops. Both types of insecticides need to be placed where larvae will contact them; these depths are defined in this study.

DYMEX models require further validation to improve the simulation of change in the abundance of populations of *A. parvulus* and *L. negatoria*. Consideration should be given

to continuing to monitor the abundance of *A. parvulus* at several sites by light-trap. Light-trap data may be less valuable for measuring changes in the abundance of *L. negatoria* as light-trap catches of this species may originate from a wider range of sites than light-trap catches of *A. parvulus*.

Damage can be minimised most effectively by targeting control measures, such as plough-out/cultivation and knockdown insecticide, at the largest of the allochronic populations. For sites sampled in this study, the largest allochronic population emerged as adults in summers beginning in even-numbered years. Plough-out/cultivation and knockdown insecticide would kill most larvae of these populations if applied during spring and summer in odd-numbered years.

Summer is a period of significant mortality for feeding-stage third instars of both species. Laboratory-derived functions describing mortality of feeding third instars due to temperature did not accurately simulate this mortality. Further work is needed to determine that mortality of feeding-stage third instars during summer is reasonably common in the field and to investigate mortality factors other than temperature that may be associated with the phenomenon.

6.0 PUBLICATIONS

- Logan D P (1995) Seasonal changes in distribution of Childers canegrub, *Antitrogus parvulus* Britton, in the soil profile. *Proceedings of the Australian Society of Sugar Cane Technologists* 17:110-115.
- Logan D P (1996) Soil distribution of noxia canegrubs and the effect of plough-out on numbers. *Proceedings of the Australian Society of Sugar Cane Technologists* 18:71-77.
- Logan D P (1997) Effect of soil moisture on oviposition by Childers canegrub, *Antitrogus parvulus* Britton (Coleoptera: Scarabaeidae). *Australian Journal of Entomology* 36:175-178.
- Logan D P (1997) Distribution of eggs and larvae of Childers canegrub, *Antitrogus parvulus* Britton (Coleoptera: Scarabaeidae), in relation to patches of canegrub-damaged sugarcane. In Allsopp P G, Rogers D J and Robertson L N (eds) *Soil invertebrates in 1997*, pp. 52-55. BSES: Brisbane.
- Logan, D P (1998) Mortality in third instars of the canegrubs, *Antitrogus parvulus* Britton and *Lepidiota negatoria* Blackburn (Coleoptera: Scarabaeidae) in southern Queensland. *Proceedings of the 4th International Workshop on Microbial Control of Soil Dwelling Pests. AgResearch, Lincoln* (in press).

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9.0 APPENDICES

- Appendix 1 Logan, D P (1995) Seasonal changes in distribution of Childers canegrub, *Antitrogus parvulus* Britton, in the soil profile. *Proceedings of the Australian Society of Sugar Cane Technologists* 17: 110-115.
- Appendix 2 Logan, D P (1996) Soil distribution of noxia canegrubs and the effect of plough-out on numbers. *Proceedings of the Australian Society of Sugar Cane Technologists* 18: 71-77.
- Appendix 3 Logan, D P (1997) Effect of soil moisture on oviposition by Childers canegrub, *Antitrogus parvulus* Britton (Coleoptera: Scarabaeidae). *Australian Journal of Entomology* 36: 175-178.
- Appendix 4 Logan, D P (1997) Distribution of eggs and larvae of Childers canegrub, *Antitrogus parvulus* Britton (Coleoptera: Scarabaeidae), in relation to patches of canegrub-damaged sugarcane. In Allsopp P G, Rogers D J and Robertson L N (eds) *Soil invertebrates in 1997*, pp 52-55. BSES: Brisbane.
- Appendix 5 Logan, D P (1998) Mortality in third instars of the canegrubs, *Antitrogus parvulus* Britton and *Lepidiota negatoria* Blackburn (Coleoptera: Scarabaeidae) in southern Queensland. *Proceedings of the 4th International Workshop on Microbial Control of Soil Dwelling Pests. AgResearch, Lincoln*. (in press).
- Appendix 6 Outline of PhD thesis.