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Sampling and dispersion of *Pterohelaeus alternatus* Pascoe and *Gonocephalum macleayi* (Blackburn) (Coleoptera: Tenebrionidae) larvae in soil

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Abstract

Late-stage larvae of *Pterohelaeus alternatus* Pascoe and *Gonocephalum macleayi* (Blackburn) were found to be randomly dispersed in the soil in fallow fields and within crop rows in the Central Highlands of Queensland. Using a 0.032 m^2 sample unit, variance increased with mean density, obeying Taylor's power law. Square root transformation stabilised the variance. Over 90% of *P. alternatus* larvae were under plants in a row crop, with none in the centre of the inter-row space. Despite low soil moisture levels (*ca.* 14%), 74 to 91% of larvae were in the top 70 mm of soil. In a fallow field *G. macleayi* numbers were 2.7 times higher under aggregations of crop residue than the mean over the whole field.

Fifty to 100 samples were required to attain 20% SE of $\bar{x}$ at densities of 15 to 25/m^2, involving 2 to 4 man-hours sampling. Sampling low density populations (1-4/m^2) would be prohibitive.

INTRODUCTION

False wireworms are one of the most serious pests of seedling crops in Queensland, damaging a wide variety of field crops throughout the State (Allsopp and Lloyd 1982). The main species in central Queensland are *Pterohelaeus alternatus* Pascoe and *Gonocephalum macleayi* (Blackburn) (Allsopp 1979). False wireworm larvae are present during winter and spring and damage spring-sown crops, while adults attack summer and autumn plantings. Larvae are more troublesome in southern districts, whereas adults are the most damaging stage in central and northern regions (Allsopp 1981; Murray and Wicks 1984). Sunflower seedlings are very susceptible as seedling losses cannot be compensated for by increased yield of survivors (Forrester 1980).

In 1978, 8000 ha of sunflower on the Central Highlands was destroyed by soil insects (largely *P. alternatus* and *G. macleayi* adults) with much of the remaining 70 000 ha thinned by seedling deaths (McLaughlin 1978).

Allsopp (1980) stressed the urgent need for research on false wireworm population dynamics and economic damage thresholds, as well as improved controls. The determination of economically damaging levels and the rational use of control strategies rely on accurate assessment of pest population densities. Statistically-sound sampling methods are essential, and these are lacking for most soil insect pests in Queensland. Control decisions, based on potentially damaging population levels, need to be made before planting, otherwise delay in treatment could result in unacceptable levels of plant stand thinning by false wireworms (Murray and Spackman 1983). No simple method of assessing larval density has been developed, apart from the laborious method of examining soil samples.

Records of damaging levels of false wireworm larvae in Australia include 11/m^2 for *Saragus* sp. in South Australia (Allen 1968), 11/m^2 for either *P. darlingensis, G. macleayi* or *Saragus magister* Pascoe in northern NSW (Forrester 1980), and 10–20/m^2 for *Pterohelaeus* sp. in NSW (Goodyer 1983). Forrester (1980) suggested that at least 10 soil samples

each of 0.09 m^2 surface area should be examined from across each field. Goodyer (1983) advocated the removal of 'a number' of samples of 0.0225 m^2 randomly selected from each field. He further indicated that samples should be taken deeper when the soil is dry. Allsopp (1979) similarly advised sampling 'small random areas' and varying the sampling depth depending on the depth of the moist layer, since larvae were found just above this layer. None of these studies indicated how the damage thresholds were calculated nor the levels of precision in the population density estimates. The SORPACK sorghum management model (Elder 1986) uses a threshold of two false wireworms or more in 30 samples, each of 0.09 m^2, taken to the moist layer of soil.

This paper provides information on the intrapaddock dispersion of *P. alternatus* and *G. macleayi* on the Central Highlands.

MATERIALS AND METHODS

Populations of *P. alternatus* larvae were sampled eight times, and *G. macleayi* seven times during September and October 1987. Samples of 0.032 m^2 surface area (one spade-square) were removed and hand-sieved on a flat, metal tray with 60 mm upturned edges to retain soil and soil insects. Larvae were identified and counted in the field, and were subsequently weighed. Both random and centric systematic area-sample (CSS) (Milne 1959) methods of sampling were used.

Row crops impose a high degree of stratification within fields,and the distribution of root-feeding insects is linked to the rows of plants (Robertson 1984). To determine the lateral dispersion of false wireworm in relation to plants, samples were taken from under plants and in a series of adjoining samples to the centre of the inter-row space.

False wireworms also feed on decomposing organic matter in and on soil (Allsopp and Lloyd 1982), and local trash concentrations may influence density estimates. This was studied by selecting concentrations of previous crop residue as sampling points and comparing the resultant density with overall field mean.

Number of samples per study area

The number of samples taken depends on the objectives of the study and the level of accuracy required for population estimates. A density estimate with ± 25% SE is sufficient to detect a doubling or halving of populations over time, or between treatments (Southwood 1978). In this study, the number of samples needed to achieve 20% SE, were calculated by using the relationship, $N = (s/p\bar{x})^2$, where N = no. samples required to give p = predetermined SE as a proportion of $\bar{x}$, and s = estimated standard deviation (Southwood 1978).

RESULTS

Population parameters

Mean and variances from sampling during September and October 1987 for *P. alternatus* and *G. macleayi* are given in Table 1. Sample variance increased with the mean for both species, obeying Taylor's power law (Southwood 1978). The relationships were:

$$\ln s^2 = 0.62 + 1.32 \ln x,\ R^2 = 0.96 \text{ (}G.\ macleayi\text{); and}$$

$$\ln s^2 = 0.44 + 1.12 \ln x,\ R^2 = 0.97 \text{ (}P.\ alternatus\text{).}$$

The two regression lines are not significantly different (slopes $F_{(1,12)} = 2.33$; intercepts $F_{(1,11)} = 0.11$).

Table 1. Population parameters derived from sampling eight *P. alternatus* and seven *G. macleayi* populations with 180 × 180 mm spade square samples during September and October 1987

No. of samples (*No*)	Sample mean ($\bar{x}$)	Variance (s^2)	$\frac{s^2}{\bar{x}}$	Distribution model	No. of samples for 20% SE of $\bar{x}$
(A) *Pterohelaeus alternatus*					
20	0.65	1.44	2.22	neg. binom.	88
10	0.60	0.71	1.19	Poisson	50
20	0.50	0.79	1.58	Poisson	80
30	0.53	0.53	1.0	Poisson	47
30	0.03	0.03	1.0	Poisson	743
42	0.57	0.89	1.56	neg. binom.	60
30	0.13	0.19	1.46	Poisson	266
20	0.25	0.30	1.20	Poisson	120
(B) *Gonocephalum macleayi*					
30	0.07	0.06	0.86	Poisson	328
30	0.77	1.98	2.57	neg. binom.	84
30	0.47	0.88	1.87	neg. binom.	100
24	0.38	0.43	1.13	Poisson	74
20	0.15	0.13	0.87	Poisson	144
30	0.40	0.45	1.13	Poisson	70
10	2.10	4.10	1.95	neg. binom.	23

When comparing sample data, parametric statistical tests assume the variance is independent from the mean. The choice of a transformation statistic (q) to stabilise the variance is related to the value of b. From the equation $q = 1 - b/2$, where $b = 1.32$ and 1.12 (above) $q = 0.34$ and 0.44. This indicates that a square root ($q = 0.5$) transformation is an adequate transformation (Southwood 1978); for example, when analysing sample data from pest control treatments.

Populations of both species were tested for goodness of fit to the negative binomial model using the test based on the second moment (variance) and to the Poisson distribution by the index of dispersion (Southwood 1978). Most populations were found to have Poisson distribution. The relatively low values of the sample means may have influenced the type of distribution, as Waters (1955) noted that low density populations often fit the Poisson model, despite aggregation at higher density. Late stage larvae, however, often tend toward random dispersion as larvae move away from egg-laying sites during development (King *et al.* 1981).

The number of samples required to give 20% SE of $\bar{x}$ varied with density, from *ca.* 50–80 for *P. alternatus* and *ca.* 70–100 for *G. macleayi* over the density range 15 to 25/m² (0.5 to 0.8 larvae per sample) (Table 1). Determination of means with this level of error is not feasible for low density populations (1 to 4/m²) due to the large number of samples required (Table 1).

Distribution and depth of *P. alternatus* in a row crop

A 20 ha field of chickpea sown in 1 m wide rows at 50 000 plants/ha was sampled at Emerald. Ninety-one percent of *P. alternatus* larvae were in samples taken under plants and the remainder were in samples taken adjacent to the rows. No larvae were found in the inter-row space ($N = 20$ samples at each position, $\bar{x} = 0.5 \pm 0.2$ larvae per sample in row). Sampling under plants on two other occasions showed that 74% and 91% of larvae were in the upper 70 mm of soil, the remainder between 70 and 150 mm deep.

Soil moisture was 12 to 16% (gravimetrically determined) in the upper 100 mm; that is, below the permanent wilting point for the heavy black cracking clay soil.

Sampling in a limited area of relatively high numbers of *P. alternatus* in a crop of chickpea was conducted to determine intra-row and inter-row distribution. Eight consecutive plants in each of four adjacent rows were sampled giving a mean of 1.19 larvae per sample (that is, per plant). There was no significant difference in density between rows ($F_{(3,21)}= 0.37$) or between plants within rows $F_{7,21)}= 0.49$). Dispersion between plants was approximately random; the variance mean ratio was 0.95.

Distribution of *G. macleayi* in relation to organic matter

Significantly ($P<0.05$) more larvae were found under residues of previous sunflower plants, compared to the mean of the random sample in clay soil near Clermont in early October 1987. The densities were 62/m² (± 19/m² SE) and 22/m² (± 8/m² SE) respectively. All larvae were in the upper 70 mm of soil, with moisture levels at field capacity when sampled.

DISCUSSION

Late stage larvae of both *P. alternatus* and *G. macleayi* on the Central Highlands are randomly dispersed. Their relatively large size makes them easy to detect in soil samples in September–October. Most summer crops in southern Queensland are planted at this time and this is when sampling for soil insects is most relevant. Summer crops in central Queensland are planted in spring or January–February with sunflower particularly planted later in the season (Murray *et al.* 1987). Soil sampling for larvae is essential prior to spring sowing, but baiting to assess adult false wireworm and other soil insects is appropriate for the later-planted crops in Central Queensland (Murray and Wicks 1984).

The number of samples required to give population estimates within 20% SE is large, even for the highest density populations studied. Thirty samples can be processed over areas of *ca.* 10 ha in 1 hour using CSS methods. Larger fields take more time due to the distances between sampling points. Random sampling takes longer than CSS, and Milne (1959) showed that the latter method was as good at providing statistically accurate population parameters as was true random sampling.

Care must be exercised in spade-sampling, to avoid counting insects which fall into the hole from surrounding soil. These lead to over-estimation of population density (King *et al.* 1981).

Murray *et al.* (1987) noted that soil insects including false wireworm adults congregated under trash, especially after rain. This study showed that false wireworm larvae were abundant under crop residue when soil was moist. Radford and Allsopp (1987) noted that rainfall stimulated false wireworm larvae to move upward in the soil profile, causing damage to crops. The timing of sampling is important and should be left until moisture levels are close to those required for crop establishment. Deep sampling, necessary in dry fallows, is more time-consuming and the greater volume of soil may lower the efficiency of insect recovery. Sampling should closely precede planting, with shallow samples taken from moist soil.

Planting summer crops immediately after removal of a winter crop may require sampling in the rows of the winter crop. Insect numbers recovered from under plants in rows require adjustment to whole field estimates (Robertson 1984). The 180 × 180 mm spade-square samples over the row in 1 m wide rows samples 0.18 of the total row plus inter-row area, so the mean number per square metre on row must be multiplied by 0.18

to obtain the whole-field average. For this example, it is assumed that average plant spacing within rows does not exceed 180 mm and that all false wireworms are under plants on the row (see above for *P. alternatus* in a row crop).

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