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Cereal aphid populations and the relation between mean density and spatial variance

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Abstract

Analysis of field samples of the aphid *Sitobion avenae on winter wheat* revealed that the power-relation between mean density and between-tiller variance did not change during the seasonal growth and decline of the aphid population. A single equation, therefore, could be used throughout the season to calculate the optimal sample size – the number of tillers that must be examined to yield an accurate estimate of aphid density.

Additional keywords: Sitobion avenae, wheat

Introduction

An essential feature of any programme of supervised pest control is estimation of the density of pests per crop plant. Clearly, the accuracy of any such estimate increases with the number of crop plants sampled, but intensive sampling is very time-consuming. For this reason it is desirable that the sample size be just large enough to yield the required accuracy.

In studies of insect populations the most commonly used definition of accuracy is the ratio of the standard error, or of the 95% confidence limits, to the mean. The standard error, SE, is given by

$$SE = (\sigma^2/n)^{1/2} \tag{1}$$

where σ^2 is the spatial variance and n is the sample size. If we require that the ratio of SE to the mean, μ, is not greater than C (conventionally 0.1), then the optimal sample size, $\hat{n}$, is

$$\hat{n} = \sigma^2/C^2\mu^2 \tag{2}$$

Calculation of $\hat{n}$ must therefore be based on estimates of the variance, as well as the mean density. Karandinos (1976) describes several ways of estimating σ^2 from preliminary measurements of the mean, or using the results of previous samples. These methods, however, are based on assumptions about the form of the population's distribution (Poisson, negative binomial, binomial etc.), assumptions which are unlikely to hold for many species; the parameter k, of the negative binomial distribution often varies with μ (Taylor et al., 1979; Rabbinge et al., 1984), and the *form* of the distribution may change during the development of the population (Rabbinge and Mantel, 1981). An alternative method, used for the cereal aphid *Sitobion avenae* (F.) (Ward et al., 1985a) is based on the relation between variance and mean (Taylor, 1961), which has been shown to fit data on a wide range of species (Taylor et al., 1978, 1980). Here, the variance is proportional to a rational power of the mean:

$$\sigma^2 = A\mu^B \tag{3}$$

where A and B are positive constants to be estimated by regression.

Before this equation can be used in the construction of a sampling programme, however, it must be shown to be constant throughout the development of the pest population; it is known, for example, that rates of reproduction, mortality and migration influence both A and B (Anderson et al., 1982), and predator activity may have important effects on the distribution of the prey (Roitberg and Myers, 1978).

In this article, the results of field sampling of the aphid *S. avenae* are used to test whether the relation between mean and variance changes during the growth season. The data used were collected in Sussex during 1980, a year in which the abundance of aphid-specific predators varied considerably, and in which predators were responsible for the decline of the aphid population in June (Chambers et al., 1986).

Material and methods

Sampling. S. avenae were sampled, by two (occasionally three) experienced samplers, on early-sown winter wheat during May and June 1980, at ten sites in five fields on North Farm, Washington, Sussex. Each sampler counted the aphids on each of 25 tillers in a small area (about ½ m^2), then moved before sampling further. The mean density and between-tiller variance were calculated for each group of 25 tillers.

Analysis. Results from four sample dates were used: 9 June, 16 June and 25 June. These represent the early exponential growth phase, peak aphid density with little predation, peak density after the appearance of large numbers of aphid-specific predators, and the subsequent collapse of the aphid population. The development stages of the wheat on these four dates were: 1st-2nd node (DC 31-32) (Zadoks et al., 1974); flowering (DC 61-65); watery ripe (DC 71) and milky ripe (DC 73).

Logarithms of the sample means (m) and variances (S^2) were taken, and a regression was calculated for each sample date, to give equations of the form

$$\log S^2 = a + b \log m \tag{4}$$

An analysis of covariance was performed to test whether the parameters a an b varied sample dates.

Table 1. Linear regressions of log S^2 (spatial variance) on log m (mean aphid density), for sample of *S. avenae* on winter wheat on four dates in 1980.

Date (1980)	Intercept	Slope	N	r	p
6 May	0.56	1.44	79	0.95	***
9 June	0.49	1.59	54	0.87	***
16 June	0.52	1.53	57	0.72	***
26 June	0.47	1.38	62	0.93	***

***: $p<0.001$; N = number of groups of 25 tillers examined.

Results

The regressions for the four sample dates are presented in Table 1. All show highly significant correlations between m and S^2. Inspection suggests that the slope increases and declines as the population rises and falls, or with the changes in the ratio of adults to nymphs through the reason.

Table 2 summarizes the results of the analysis of covariance. There is no statistical support for the existence of any variation in the slopes of the regressions. Neither the slope nor the intercept of the variance-mean regression varies significantly among sample dates.

Throughout the season, therefore, the data are adequately described by a single equation:

$$\log S^2 = 0.52 + 1.43 \log m \tag{5}$$

($r = 0.97$, 250 d.f., $p<0.001$) (Fig. 1).
The optimal sample size can thus be calculated throughout the season as (from equation 2)

Table 2. Analysis of covariance, log S^2 versus log m, for the four samples of *S. avenae*.

	χ^2	d.f.	F	P
Homogeneity of variance (Bartlett's test)	2.51	3	–	NS
One line rather than one mean	–	1, 250	4237.8	***
Lines with common slope rather than one line (i.e.) different intercepts)	–	3, 247	0.92	NS
Individual lines rather than Lines with common slopes (i.e. different slopes)	–	3, 244	1.76	NS
Individual lines rather than one line:	–	6, 244	1.35	NS

NS: $p> 0.005$; ***: $p<0.001$.
d.f. = degrees of freedom; F = variance ratio.

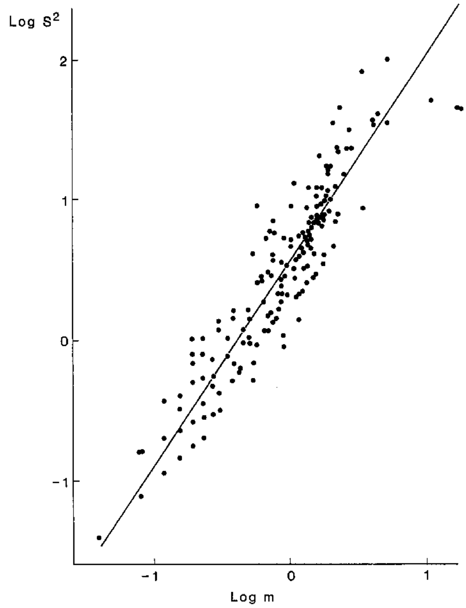

Fig. 1. Relation between the logarithm of the sample variance (log S^2) and the logarithm of the sample mean (log m), for *Sitobion avenae* on groups of 25 winter wheat tillers in May and June 1980.

$$\hat{n} = \frac{3.33\mu^{-0.57}}{C^2} \tag{6}$$

(Ward et al., 1985a).

Discussion

Effective control of pests requires that changing levels of population density be monitored accurately. To estimate the minimum sample size needed to yield the desired accuracy it is necessary to estimate the variance in the number of pest individuals per sampling unit. The method used by Ward et al. (1985a, 1985b) relies on the power relation described by Taylor (1961). Although predation may affect the distribution of aphids (Roitberg and Myers, 1978), this paper has shown that the rapid increase in the abundance of aphid-specific predators in Sussex during June, 1980, did not alter either of the parameters of the relation between mean density and spatial variance in *S. avenae*. The equation derived could thus be used throughout the season to calculate the optimal sample size. Further research is necessary, however, to determine whether the variance-mean relation is influenced by changes in the age structure of the population, or by larger changes in density than were observed here, and thus to what extent this result can be generalized to other populations of cereal aphids.

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Samenvatting

Graanluispopulaties en de relatie tussen de gemiddelde populatiedichtheid en de ruimtelijke variantie

Teneinde de tijd nodig voor het tellen van graanluizen te beperken kan een minimale monstergrootte bepaald worden bij een van te voren vastgestelde nauwkeurigheid. Om deze monstergrootte uit te kunnen rekenen aan de hand van een voorspelling van de dichtheid moet er een betrouwbare relatie bestaan tussen de gemiddelde dichtheid en de ruimtelijke variantie. Uit analyse van veldgegevens voor de graanluis *Sitobion avenae* blijkt dat een dergelijke relatie bestaat, en dat deze constant blijft tijdens het hele groeiseizoen.

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This book is about the breeding of field crops, notably those of temperate climates (although rice and cotton are included). This is the second volume of two. It deals with specific crop types (the first volume is on general aspects of plant breeding). Aspects treated by crop are: systematics, biology, genetics, breeding aims, hybridization techniques and selection methods. Among breeding aims, some attention is paid to resistance to pests and diseases, about 30 of the 424 pages of text deal with resistance, of which 10 to potato pests and diseases. This book has the same format and typography as the one reviewed on page 113-114 of this issue.

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