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The use of incidence counts for estimation of aphid populations. 2. Confidence intervals from fixed sample sizes

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Abstract

Two approaches have been used in the monitoring of local populations of cereal aphids: direct counting of aphids on a number of tillers, and the less time-consuming assessment of incidence levels (the proportion of tillers infested). This paper compares the accuracy of these two methods, using a fixed sample size, as is desirable in a practical monitoring system. It is shown that the two methods are equally reliable over a range of incidence levels, but that the confidence intervals for the population density are very broad. Reduction of these sampling errors requires a considerable increase in sample size, so they should instead be taken into account in the management decision-making process.

Additional keywords: cereal aphids, sampling, accuracy.

Introduction

Flexible supervised control of cereal aphids requires adequate monitoring of the changes in population density; that is, any monitoring system should be simple, reliable and accurate, and require only a limited amount of time. It has been suggested (Rabbinge and Mantel, 1981, 1982) that, in order to reduce the time required, farmers should use incidence counts – estimating the proportion of wheat tillers infested – instead of the more laborious direct counting of aphids.

A previous paper (Ward et al., 1985) has calculated the minimum sample sizes required for incidence counts to yield a given accuracy of population estimation. It was shown that the required sample size varied considerably with aphid density. For regular monitoring by research workers, flexibility in sampling procedure seems feasible. For use by farmers, however, a more uniform and rigid system is desirable, e.g. one in which a fixed number of tillers is inspected on each sample date.

This paper examines the reliability of such a rigid system. It calculates the confidence limits for population estimates made using incidence counts, for two different density-incidence relations and over the full range of incidence levels.

Materials and methods

1. Incidence counts and mean aphid density. Two empirical relations have been used as a basis for calculating aphid density from incidence counts. The equations used here are:

$$\log \mu = -3.066 + 0.662 \text{ Probit (P)} \quad (1)$$

on the total aphid density per tiller (data from Rabbinge and Mantel, 1981); and

$$\log \mu = 0.331 + 1.132 \log [\ln (\frac{1}{1 - P})] \quad (2)$$

(fitted to data on *Sitobion avenae* by Ward et al., in prep. b), where μ is the mean aphid density and P is the proportion of tillers infested.

2. Confidence limits of population estimates based on incidence counts. Estimates of P from field counts are subject to sampling error. The 95% confidence limits for P, for a given sample size, can be obtained from statistical tables (e.g., Pearson and Hartley, 1956) and substituted directly into equations 1 and 2 to give the confidence interval for μ. Thus, for the purposes of illustration, it is assumed that the relations provide a precise description of the field conditions for which they were produced.

3. Confidence limits for direct counting. It has been shown (Ward et al., in prep. a) that the between-tiller variance in aphid density is related to the mean density as:

$$\text{Var(x)} = 3.327 \cdot \mu^{1.427}. \quad (3)$$

The 95% confidence limits for μ are equal to m ± 1.96 x SEM, where m is the estimated mean density, and SEM the standard error of the mean, is given by:

$$\text{SEM} = \frac{\text{Var(x)}}{n} = \frac{1.824 \cdot \mu^{0.714}}{n} \quad (4)$$

(n is the sample size).

Equations 1, 2 and 4 can be used to calculate the confidence interval for population estimates based on incidence sampling and direct counting, over a range of incidence levels.

Results

Table 1 presents the confidence limits for population estimates in conditions fitting equation 1. The sample size is set at 100 tillers. At low and intermediate population levels, direct counting and incidence counts yield similar accuracies. As the proportion of tillers infested approaches 100%, however, direct counting becomes steadily more accurate, while the reliability of incidence counts decreases.

In Table 2 the equivalent results are given for a field system obeying equation 2. Here, as the proportion of tillers infested approaches 0% or 100%, direct counting is more accurate than the use of incidence counts. Over a wide range of intermediate

Table 1. The 95% confidence limits (CL) for aphid density, assuming the validity of equation 1. Sample size: n = 100. 'Accuracy' = 100 · [CL(U) − CL(L)]/2m.

Proportion of tillers infested	Mean density (= m)	Direct counting			Incidence counts		
		lower CL(L)	upper CL(U)	accuracy	lower CL(U)	upper CL(U)	accuracy
0.05	0.143	0.05	0.23	62.9	0.06	0.28	76.9
0.1	0.249	0.12	0.38	52.2	0.14	0.43	58.2
0.2	0.486	0.27	0.70	44.2	0.30	0.76	47.3
0.3	0.789	0.49	1.09	38.0	0.52	1.19	42.5
0.4	1.192	0.79	1.60	34.0	0.81	1.79	41.1
0.5	1.754	1.22	2.29	30.5	1.19	2.58	39.6
0.6	2.580	1.88	3.28	27.1	1.72	3.82	40.7
0.7	3.901	2.96	4.85	24.2	2.58	5.90	42.6
0.8	6.326	4.99	7.66	21.1	4.07	10.12	47.8
0.9	12.371	10.22	14.52	17.4	7.08	21.53	58.4
0.95	21.524	18.33	24.72	14.8	10.91	49.97	90.7

levels, however, the two methods are equally reliable.

An important feature of these results, however, is that the upper limit of the confidence interval is normally at least twice as high as the lower limit. To reduce the uncertainty to any significant extent would require considerable increases in sample size, since the error is inversely proportional to the square root of n: halving the confidence interval would require a quadrupling of n.

Table 2. The 95% confidence limits (CL) for aphid density, assuming the validity of equation 2. Sample size: n = 100. 'Accuracy' = 100 · [CL(U) − CL(L)]/2m.

Proportion of tillers infested	Mean density (= m)	Direct counting			Incidence counts		
		lower CL(L)	upper CL(U)	accuracy	lower CL(U)	upper CL(U)	accuracy
0.05	0.074	0.02	0.13	74.3	0.02	0.20	121.6
0.1	0.168	0.07	0.27	59.5	0.07	0.34	80.4
0.2	0.392	0.21	0.58	47.2	0.22	0.64	53.6
0.3	0.667	0.40	0.94	40.5	0.42	1.00	43.5
0.4	1.002	0.64	1.36	35.9	0.68	1.44	37.9
0.5	1.415	0.96	1.87	32.2	1.00	1.94	33.2
0.6	1.941	1.37	2.52	29.6	1.39	2.60	31.2
0.7	2.644	1.93	3.36	27.0	1.94	3.51	29.7
0.8	3.672	2.77	4.58	24.6	2.73	4.91	29.7
0.9	5.508	4.30	6.72	22.0	3.94	7.41	31.5
0.95	7.420	5.93	8.92	20.1	5.13	10.86	38.6

Discussion

The results presented above suggest that, over a wide range of low and intermediate aphid densities, direct counting and the use of incidence counts are equally reliable. At higher densities, incidence counts become increasingly inaccurate, but direct counting becomes prohibitively time-consuming. One possibility here is to use counts of the proportion of tillers infested by more than, e.g., ten aphids, since this also is related to the mean density (Rabbinge and Mantel, in prep.). As regards the choice of sampling method, therefore, incidence counts (or measures of the proportion tillers on which aphid density exceeds some threshold) seem preferable to direct counting.

A second feature of the results, however, is that both methods result in considerable errors in population estimates. Reducing these errors significantly would require unacceptable increases in sample size.

Since sampling errors cannot be eliminated, they must be taken into account in the process of management decision-making. One approach here would be to base decisions on the assumption that true aphid density is equal to the upper limit of the confidence interval. While this would avoid the destructive error of omitting necessary pesticide applications, it would result in a great deal of unnecessary spraying. A preferable alternative involves the use of stochastic optimization (e.g. Wagner, 1969; Van Beek and Hendriks, 1983). Here, realistic computer models of the system can be used to calculate the expected damage for the range of possible aphid densities. The expected costs (and therefore the benefits of insecticide application) can then be determined, using the sampling error probability distribution to calculate a weighted mean damage level. Alternatively, the spraying decision could be based on risk-aversion: to minimize the probability that costs incurred exceed some maximum acceptable value (Rossing, 1983). Whatever the goal of management, however, (i.e., to minimize expected costs or to reduce risks) the sampling errors calculated above must not be ignored.

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Samenvatting

Het gebruik van bezettingspercentages voor het schatten van bladluispopulatiedichtheid. 2. Betrouwbaarheidsintervallen bij constante steekproefomvang

Er worden doorgaans twee methoden gebruikt om de dichtheid van graanluizen vast te stellen: directe telling en bepaling van het bezettingspercentage. De nauwkeurigheid van deze twee methoden wordt hier vergeleken bij een constante monstergrootte, die gewenst is bij praktische waarnemingssystemen. De beide methoden zijn even betrouwbaar over een reeks van bezettingspercentages, maar de betrouwbaarheidsintervallen zijn erg ruim. Verkleining van deze bemonsteringsfouten vereist een aanzienlijke toename van de monstergrootte, zodat het waarschijnlijk beter is deze fouten in het beslissingsproces voor de bestrijding te betrekken.

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