A rapid method of sampling for aphids on strawberries

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ABSTRACT

A rapid system of sampling for strawberry aphids, *Chaetosiphon fragaefolii* (Cockerell) was developed for use by pest management scouts. Regression equations relating mean numbers of aphids/leaf, variances of those means and the proportion of unifested leaves (P_0) were developed from samples of aphids from single leaves. Using the equations, mean aphid density per leaf and standard errors can be estimated from P_0 and the sample size. The accuracy of the estimations were tested on data from 155 samples from commercial strawberry fields sampled by a professional pest management company. Means estimated from P_0 were sufficiently accurate for the intended purpose and only 2 hours were required to sample 300 leaves compared to 16 hours when all aphids on all leaves were counted from only 80 leaves. An electronic recorder was programmed to prompt an IPM scout for data entry, allow correction of errors and permit sampling from different subplots within a field.

INTRODUCTION

Sixteen species of aphids have been recorded on species of *Fragaria* worldwide (Blackman and Eastop 1984). All but two species have been found in south-western British Columbia, but only nine have been collected from strawberries (Forbes and Chan 1987). The strawberry aphid (*Chaetosiphon fragaefolii* [Cockerell]), of North American origin, is present in most commercial strawberry growing areas of the world. Aphids of all species cause infrequent and limited direct damage to strawberries, but plant viruses transmitted by aphids are responsible for major economic losses and increased costs of production in B.C. and most other areas of commercial strawberry production (Aerts, 1973).

C. fragaefolii is the most numerous and efficient vector of viruses transmissable to strawberries by aphids (Mellor and Forbes, 1960; Frazier and Converse 1980). Virus infection results in a progressive decline in vigor and yield (Martin and Converse, 1977) that necessitates replanting. In California, yields are commercially acceptable for only 15 to 18 months (Trumble *et al.*, 1983). In B.C., replanting is required every 3 to 5 years depending upon the degree of isolation between fields.

Strategies to protect strawberries from virus infection vary regionally depending upon the aphid fauna, virus complex and adequacy of certification programs to produce virus-free plants. Insecticide applications can reduce aphid numbers and retard the spread of viruses, but even when aphid numbers are very low, plants can become infected by one or more viruses within their first year of field exposure (Converse and Aliniazee, 1987). Breeding strawberries for tolerance to viruses and controlling aphids reduces damage and virus spread thereby prolonging plant vigour (Barritt and Daubeny, 1982). Even well-managed commercial fields of tolerant cultivars are replanted regularly because of the deleterious accumulated effects of viruses.

Modern pest management relies upon the results of sampling to make decisions about pest control. An effective sampling program must produce reliable results in a short time. Collecting 80 leaves from a field, removing and counting aphids in the laboratory can take as long as 16 hours for one person to do. Aphids must be removed to avoid counting them more than once. This is an economically unacceptable amount of effort for a grower or pest management scout.

Progress has been made (Nachman, 1984; Raworth and Merkens, 1987) in estimating the density of mites on strawberries from the proportion of pest habitats that are *not* infested (P_0). P_0 of strawberry aphids on immature leaves was correlated with the total population on individual plants (Trumble *et al.*, 1983).

This paper describes the development and testing of a method of sampling for *C. fragaefolii* based on P_0.

METHODS AND MATERIALS

Development of Sampling Program

A research plot (12 matted rows, each one meter apart and 30 m long) of Totem strawberries planted 1 May 1986, was sampled at about weekly intervals when picking, cultivation and irrigation permitted during 1987 and 1988 from 1 May until first frost in November. No insecticides were used on the plot but one application of simazine at 2.25 (ai) kg/ha for weed control was applied one month before sampling began each year.

Sampling consisted of collecting one new leaf from each of 80 plant crowns selected arbitrarily from sites evenly spaced throughout the plot. Selected leaves had elongate petioles with lamina that had not unfurled, the leaves preferred by *C. fragaefolii* (Dicker, 1952). Leaves were placed singly in plastic bags kept on crushed ice in a cooler. The number and instar of aphids on each leaf were counted and recorded after being removed from each leaf under a microscope ($\times 30$). The mean number of aphids per sample (M) and its variance (V) were calculated and ln(V) was regressed against ln(M) following Taylor (1961). The proportion of leaves that had no aphids (P_0) were calculated for each sample, transformed to $\ln(-\ln[P_0])$ and regressed against M (Nachman, 1984).

Evaluation

A private company (Monagro Consultants Inc.) sampled 27 commercial strawberry fields during 1987 to advise growers of aphid densities and give recommendations for the control of aphids. Leaves were examined in the field with a $\times 10$ magnifier mounted on a headband. The data were made available to us and consisted of 220 records of mean aphids per leaf (M), the sample size (N) and P_0. We were not given the age, cultivar, location or history of pesticide applications of the sampled fields. Samples from less than 40 leaves were discarded, leaving 155 samples for analysis.

Statistical analyses were done with SPSS-PC+ (SPSS Inc.) on a CompaQ Deskpro 286 microcomputer. The level of significance used for hypothesis testing was 5%.

RESULTS

Linear regressions between ln(M) and ln(V) (Taylor, 1961) (Fig. 1A) and between ln(M) and $\ln(-\ln[p_0])$ (Fig. 1B) were developed with data from the research plots.

$$\text{Eq. 1. } \ln V = 1.285 + 1.2061 \ln M \quad R^2 = 0.93 \text{ df} = 31$$

$$\text{Eq. 2. } \ln M = 0.964 + 1.0431 \ln(-\ln[p_0]) \quad r^2 = 0.97 \text{ df} = 31$$

Evaluation

A linear relationship (Fig. 1B) between ln(M) and $\ln(-\ln[p0])$ was calculated for the data from the commercial fields. The slope and intercept of the line were not significantly different from those of the relationship from the research plots (Fig. 1B). The data from the research plots and commercial fields were combined and the relationship between ln(M) and $\ln(-\ln[P_0])$ recalculated.

$$\text{Eq. 3 } \ln M = 0.964 + 1.043(\ln(-\ln P_0)) \quad r^2 = 0.87 \text{ df} = 199$$

A computer program based on a FORTRAN-77 program (Raworth and Merkens, 1987) was written in Turbo Pascal 4.0 (Borland International, Scotts Valley, California) (program available on request). For various levels of P_0 estimated from sampling, the program calculates, using equations 1 and 3, M and the standard error of M that results

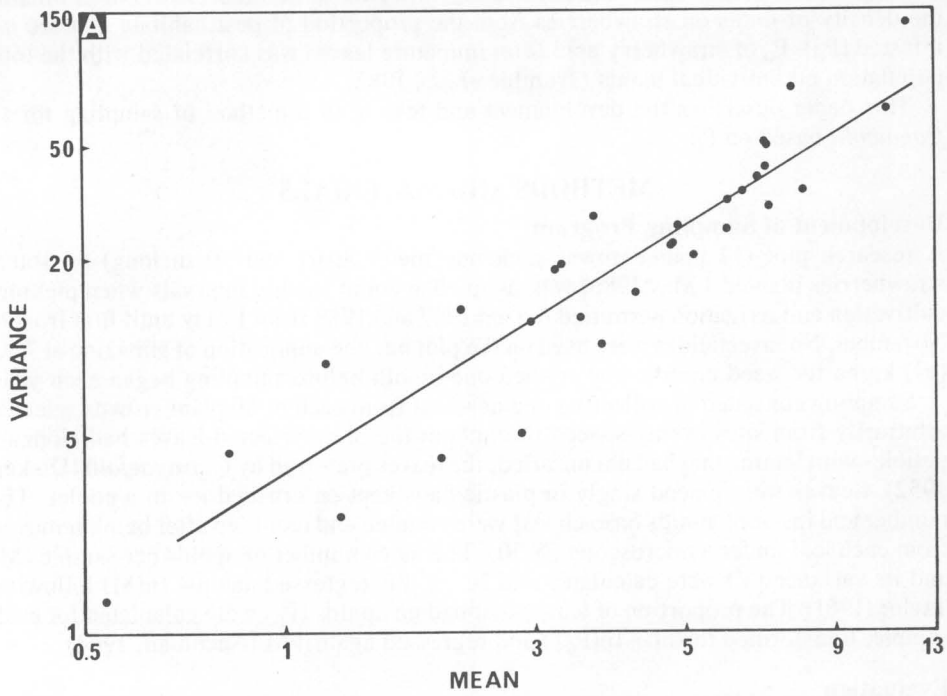

Fig. 1A. Relationship between the mean and variance in samples of *Chaetosiphon fragaefolii* from leaves in a research planting of strawberries.

when P_0 is estimated from various numbers of single leaves (Table 1). If a sample of 200 leaves were taken and P_0 was equal to 0.6, the mean level of infestation would be 1.47 aphids per leaf with a standard error of ± 0.22 (15% of 1.47, Table 1). The computer program is easily modified to print tables with gradations in P_0 and standard errors as fine as desired.

A field to be sampled was measured with the aid of a Rolatape (Rolatape Corporation, Spokane, Washington) measuring wheel and the number and spacing of rows determined. The field was then drawn to scale and a plan for sampling the field was developed.

In 1989 our interest was primarily in evaluation the utility and efficiency of the P_0 method of sampling and in determining if the edges of fields should be sampled separately from the centre of fields. While 20 commercial strawberry fields were sampled, each in a manner to answer specific research questions, results from only one are presented. That field was a 3.6 ha rectangle of 2 year old Totem strawberries. It was sampled 6 times during the growing season when agricultural operations were permitted. Sampling was done separately from each edge of the field and from two central areas separated by a road. A sample was taken approximately every 7m as the sampler walked through the field. One sample of the field required 2 hours to complete. Three hundred leaves were inspected from each field, 50 from each edge and each central strip of the field.

A model 600 Polycorder (Omnidata International, Logan, Utah) was programmed to prompt the operator for input and permit corrections to entered data. The instrument displayed a code number representing the particular area of the field being sampled and the number of leaves that had been sampled. The Polycorder stored the area code and each sample outcome (leaf with or without aphids). We programmed the instrument to request, on a relative subjective scale, the temperature, leaf wetness, cloud cover and wind speed.

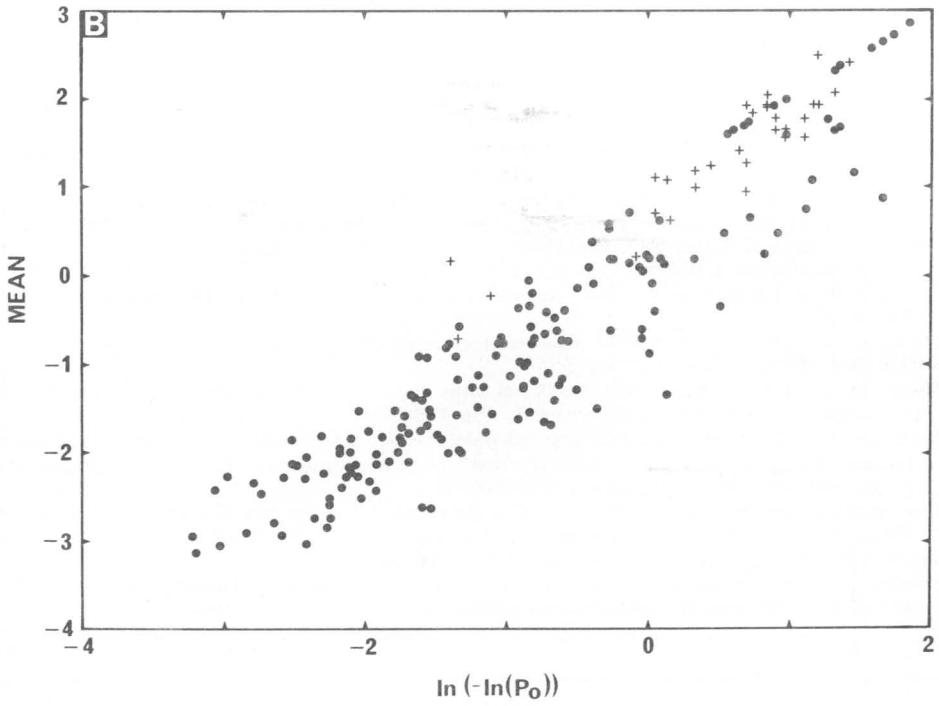

Fig. 1B. Relationship between mean number of *Chaetosiphon fragaefolii* per leaf and the proportion of uninfested leaves (P_0) in samples collected from research (+) and commercial (•) plantings of strawberries.

The data from the Polycorder were downloaded to a microcomputer for estimation of P_0 and the corresponding M. The program for the Polycorder is available from the authors. The mean density of aphids in the 6 sampled areas of the field (Table 2) was similar for most of the year except on 8 July when the edges had only one-half the density of aphids on the central subplots.

DISCUSSION

Sampling strawberry aphids on a presence or absence basis provides estimates of the mean sufficiently accurate for pest management purposes. When most leaves have aphids ($P_0 = 0.05$), aphid density exceeds 9/leaf with a variance of 53. At that level of infestation and dispersion, very heavily infested leaves are evident in every meter of row. When densities are very low (high P_0), large sample sizes would be needed to determine a mean level of infestation with accuracy. However, at low density, great accuracy is not required because further reduction of the density would not be contemplated. If the initial sample size is too low for the level of precision required, more samples can be taken before the scout leaves the field. The grower can be immediately informed of the results and future sampling scheduled at that time. The Polycorder and the programs developed to operate it, while not essential, greatly simplify recording and help the scout to be correctly oriented in large fields and to count the number of samples made.

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Table 1

Numbers of strawberry leaves, mean numbers of *Chaetosiphon fragaefolii* per leaf and standard errors resulting from observed proportions of uninfested leaves (P_0). Standard errors are expressed as percentages of means. An asterisk denotes sample sizes in excess of 10,000 leaves.

P_0	Mean	Number of Leaves at Each Standard Error									
		5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0.05	9.31	*	482	162	87	55	39	30	23	19	16
0.10	7.08	*	360	131	71	46	33	25	19	16	13
0.15	5.78	*	322	122	67	44	31	24	19	15	13
0.20	4.87	*	308	121	67	44	31	24	19	15	13
0.25	4.17	7815	306	123	69	45	32	24	19	16	13
0.30	3.60	4590	311	127	71	47	33	25	20	16	14
0.35	3.12	3553	322	133	75	49	35	27	21	17	15
0.40	2.71	3101	337	141	80	53	38	29	23	19	16
0.45	2.34	2907	359	152	86	57	41	31	25	20	17
0.50	2.02	2871	387	165	94	62	44	34	27	22	18
0.55	1.73	2962	423	181	103	68	49	37	30	24	20
0.60	1.47	3191	470	202	115	76	55	42	33	27	23
0.65	1.23	3609	534	229	131	86	62	47	37	31	26
0.70	1.01	4347	622	266	152	100	72	55	43	36	30
0.75	0.81	5764	751	319	182	120	86	65	52	42	36
0.80	0.62	9167	957	399	226	149	107	81	64	53	44
0.85	0.45	*	1332	538	302	197	141	107	85	69	58
0.90	0.28	*	2211	829	456	295	210	159	126	103	86
0.95	0.13	*	6201	1817	943	596	419	315	248	201	168

Table 2
Mean number of *Chaetosiphon fragaefolii* per strawberry leaf in six areas of a field. An asterisk indicates when means on the perimeter of field were significantly different from those of the central areas.

		Area of Field						
		Perimeter				Center		Total
Julian Day	Date	West	North	East	South	West	East	
125	May 5	0.0	0.05	0.0	0.0	0.0	0.0	0.01
151	May 31	0.16	0.10	0.16	0.10	0.16	0.16	0.14
156	June 6	0.05	0.22	0.16	0.05	0.34	0.22	0.17
189	July 8	2.50	2.10	2.10	1.40	0.54	0.50	1.42*
198	July 17	1.34	1.16	0.91	0.75	0.99	1.64	1.12
237	Aug 26	0.79	1.70	1.44	0.61	1.21	1.09	1.12

Toxicity of foliar residues of phosmet to the apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae)[1]

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ABSTRACT

Mortality of apple maggot (AM), *Rhagoletis pomonella* (Walsh), was determined in the laboratory on spray deposits of phosmet (Imidan®) applied to apple foliage and fruit at rates of 0.6 and 1.2 g active ingredient (AI)/liter (0.5 and 1 pound [AI]/100 gallons). Mortality of AM adults was 100% with both rates until 16 days post-treatment. Thereafter, mortality decreased inversely with time. Probit analysis revealed insecticide residual toxicity of 24 days for 95% mortality (ET_{95}) for both rates, and 51 and 55 days, respectively, for 50% mortality (ET_{50}) at 0.6 and 1.2 g (AI)/liter. The intercepts and slopes of probit regression were not significantly different for the two rates tested, indicating little difference between their persistence and efficacy against AM adults.

INTRODUCTION

The apple maggot (AM), *Rhagoletis pomonella* (Walsh), was first reported in the western United States near Portland, Oregon (AliNiazee and Penrose, 1981). It is now well established in six western states including Oregon, Washington, California, Idaho, Utah, and Colorado (AliNiazee and Brunner, 1986). Most AM infestations in the western United States are associated with abandoned and unsprayed apple trees and hawthorn species, both the native *Crataegus douglasii* Lindley and the introduced ornamental *C. monogyna* Jacquin. Isolated infestations of prunes in the Willamette Valley of Oregon (AliNiazee, 1985) and of cherries in Utah (Jorgensen *et al.* 1986) have also been noticed. The only commercial apple-growing area infested with AM in the western United States is near Salem, Oregon (AliNiazee, 1988).

Therefore, in Oregon and Washington, the primary objective of AM control and localized eradication programs is to kill all AM females that immigrate into commercial orchards from surrounding natural habitats before oviposition occurs. Consequently, protective application of insecticides on a regular basis against immigrating AM females is the key to successful management of AM in commercial orchards of the Pacific Northwest (AliNiazee, 1988).