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Presence-Absence Sequential Sampling for Cabbage Aphid and Green Peach Aphid (Homoptera: Aphididae) on Brussels Sprouts[1]

L. T. WILSON,[2] C. PICKEL,[3] R. C. MOUNT,[2] AND F. G. ZALOM[4]

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ABSTRACT A presence-absence sequential sampling plan. which incorporates the between-plant clumping behavior of cabbage aphid and green peach aphid, was developed for Brussels sprouts. Tentative control decision thresholds are proposed for the respective aphid species. The distribution pattern of cabbage aphid is much more clumped. as indicated by much higher density of insects for a given proportion of infested plants.

Approximately 2,200 ha of Brussels sprouts, *Brassica oleracea gemmifera*, are grown in California, with the major areas of production centered in Santa Cruz and Monterey Counties (Anonymous 1981). Four of the more common insect pests of Brussels sprouts in these areas are the cabbage maggot, ***Hylemya brassicae*** (Wiedemann), the seed corn maggot, ***Hylemya platura*** (Meigen), the cabbage aphid, ***Brevicoryne brassicae*** (L.), and the green peach aphid, ***Myzus persicae*** (Sulzer). The cabbage maggot and the seed corn maggot are normally only a problem during the seedling stage when stands are established from transplants. The cabbage aphid can become a severe problem due to the low tolerances for aphids on the marketed sprouts (<1%; Green Giant Corp., personal communication). The cabbage aphid feeds primarily on apical buds early in the season. and then moves to young sprouts. Such feeding increases the likelihood of sprout contamination during processing. The green peach aphid is rarely considered a primary pest, since it is readily controlled when plants are treated for cabbage aphid and because its feeding is largely restricted to the lower leaves, which are removed from the marketable sprouts.

An inherent problem associated with monitoring small and often abundant species such as aphids is the time required to sample a sufficient number of units (leaves. stems, branches, plants, etc.) to obtain a reliable estimate of control status or population density. Counting individual aphids is not only time consuming. but it can also be extremely difficult to obtain an unbiased estimate

[1]Received for publication 26 July 1982.
[2]Dept. of Entomology, University of California. Davis, CA 95616.
[3]U.C. Cooperative Extension, 1432 Freedom Blvd., Watsonvillr. CA 95076.
[4]U.C. Cooperative Extension. University of California. Davis. CA 95616.

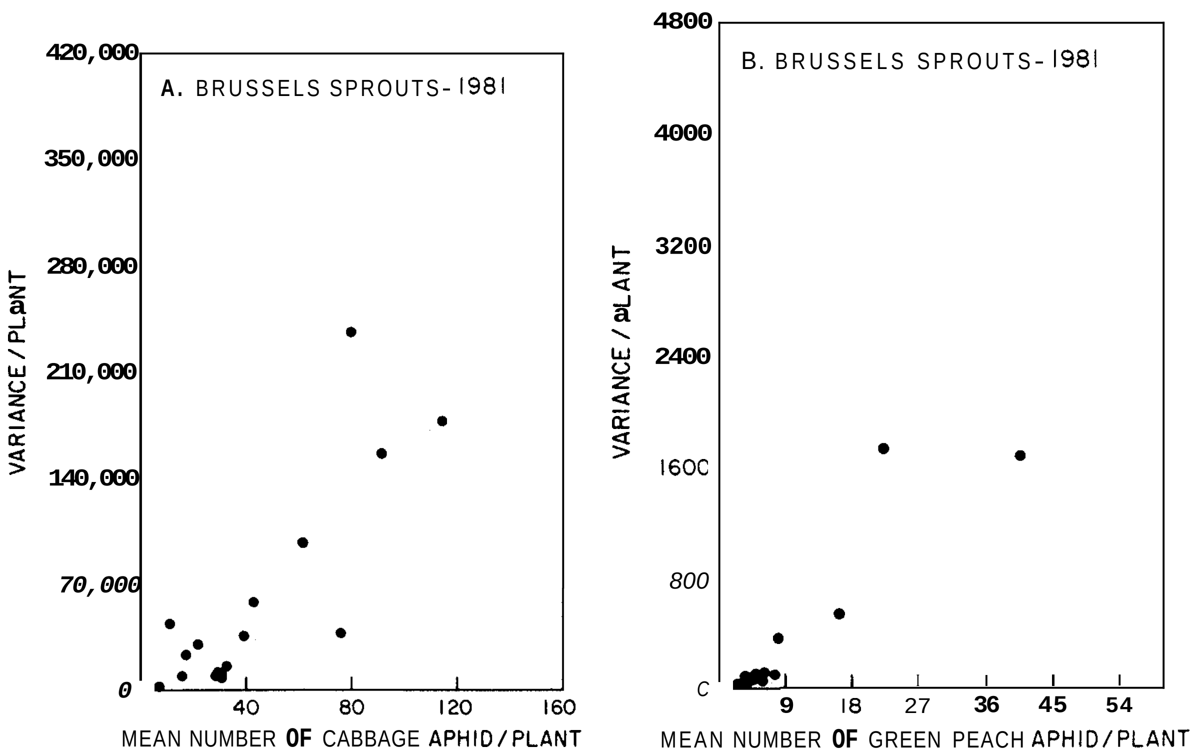

FIG. 1. Variance-mean curve for (A) cabbage aphid and (B) green peach aphid.

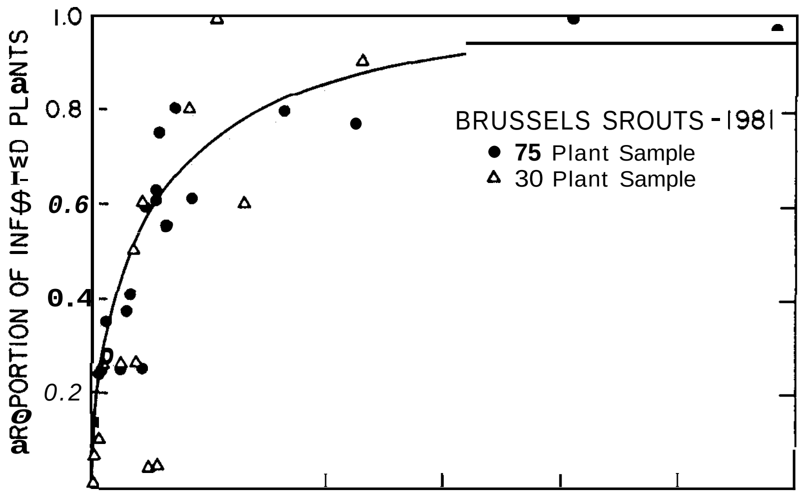

FIG. 2. Estimated and observed proportion of Brussels sprouts infested with green peach aphid as a function of aphid density.

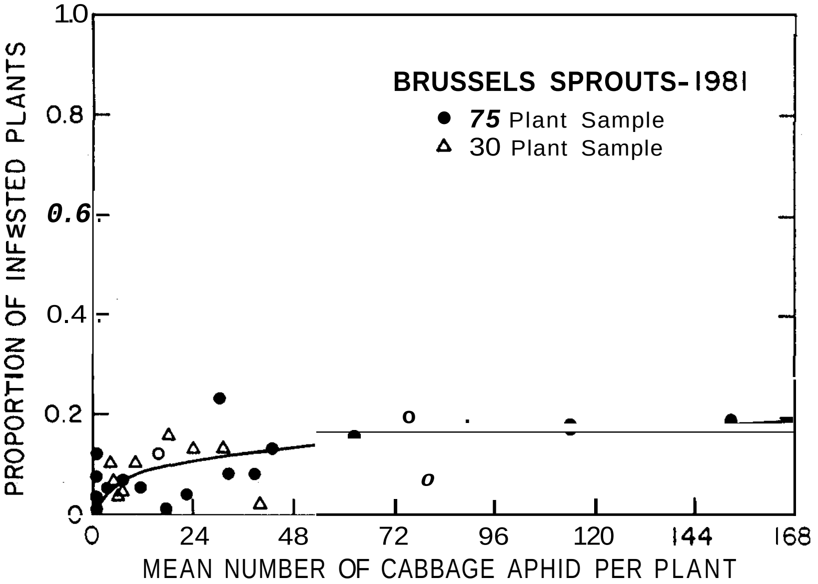

FIG. 3. Estimated and observed proportion of Brussels sprouts infested with cabbage aphid as a function of aphid density.

with conventional sampling procedures, because some aphids drop from the plant when disturbed.

This paper describes a cost-reliable binomial sequential sampling plan for cabbage aphid and green peach aphid applied to Brussels sprouts.

Materials and Methods

Four commercial fields were selected from mid-August to mid-November 1981. Three of the fields were sampled once a week; 75 plants were examined thoroughly in each field, and the numbers of cabbage aphids and green peach aphids were recorded in situ. The fourth field was sampled only three times during the season. Sampling was more intense, with a total of 30 plants examined in each of six adjoining blocks on each sample date.

Results and Discussion

Binomial Sampling

Taylor (1965, 1971) developed a variance-mean relationship applicable to species covering a wide range of distribution patterns. Wilson and Room (1982) incorporated Taylor's power law ($\hat{S}^2 = a \cdot \bar{x}^b$) into a mathematical function relating the proportion of sample units having organisms present [P(I)] to the variance and mean per unit (equation 1).

Table 1. Sequential sampling decision lines for monitoring aphids on Brussels sprouts

No. of plants sampled	No. of plants with aphids			
	Cabbage aphid		Green peach aphid	
	Don't treat	Treat	Don't treat	Treat
1	—	—	—	—
2	0	2	0	2
3	0	2	1	3
4	0	2	1	4
5	0	3	2	5
6	0	3	3	6
7	0	3	3	7
8	0	3	4	8
9	0	4	5	9
10	0	4	5	10
11	0	4	6	10
12	0	4	7	11
13	0	5	8	12
14	0	5	8	13
15	0	5	9	14
16	1	5	10	15
17	1	5	10	16
18	1	6	11	16
19	1	6	12	17
20	1	6	13	18
21	1	6	14	19
22	1	6	14	20
23	1	7	15	21
24	1	7	16	22
25	2	7	17	22
26	2	7	17	23
21	2	7	18	24
28	2	8	19	25
29	2	8	20	26
30	2	8	20	21
31	2	8	21	28
32	2	8	22	28
33	2	9	23	29
34	3	9	23	30
35	3	9	24	31
36	3	9	25	32
37	3	9	26	33
38	3	10	21	33
39	3	10	21	34
40	3	10	28	35
41	3	10	29	36
42	3	10	29	37
43	4	10	30	38
44	4	11	31	39
45	4	11	32	39
46	4	11	32	40
47	4	11	33	41
48	4	11	34	42
49	4	12	35	43
50	4	12	35	44

$$P(I) = 1 - e^{-\bar{x}\log_e(a\cdot\bar{x}^{b-1})\cdot(a\cdot\bar{x}^{b-1}-1)^{-1}} \quad (1)$$

Figure 1 illustrates the variance-mean curves for the two aphid species. Cabbage aphids are considerably more clumped in their pattern of distribution, as indicated by the more rapid rate at which the variance increases as a function of the mean. The a and b coefficients for Taylor's power law and for equation 1 were estimated for both aphids by using an iterative linear regression program (equations 2 and 3).

$$S^2 = 22.2775 \cdot \bar{x}^{1.9527},\ n = 21,\ r^2 = 0.892,\ \text{cabbage aphid} \quad (2)$$

$$S^2 = 6.5395 \cdot \bar{x}^{1.6001},\ n = 19,\ r^2 = 0.940,\ \text{green peach aphid} \quad (3)$$

The higher value of the a and b coefficients for cabbage aphid indicates the greater degree of clumping for this species. This may reflect the observation by some farmers that cabbage aphid appears to be introduced into the field during transplanting, with the result that colonies build to a high density before dispersal begins.

Derivation of the proportion infested-mean density curve was obtained for each aphid species by using the a and b coefficients from equations 2 and 3 within equation 1. The final criterion of the applicability of this technique was to compare the expected P(I) values (equation 1) with the observed data.

The fit of the curve to the green peach aphid data was quite good (Fig. 2). Regression of the expected against the observed P(I) values resulted in 85% explained variation with a forced regression coefficient (Zar 1974) of 1.02, indicating that the observed data were only slightly overestimated. Use of the iterative regression program solving directly for equation 1 also resulted in 85% explained variation, attesting to the close relationship between P(I), S^2, and $\bar{x}$ for this species.

The fit of the curve to the cabbage aphid data was poor and was attributed to the extremely high variability in the variance-mean relationship (Fig. 1). For this species, we thus chose to use the iterative regression program solving directly for equation 1. This second regression analysis resulted in a much improved fit to the data (Fig. 3) and different Taylor's coefficients (equation 4).

$$P(I) = 1 - e^{-\bar{x}(\log_e(118.7\bar{x}^{0.7948})/(118.78\bar{x}^{0.7948}-1.0))} \quad (4)$$

where $r^2 = 0.38$; $P < 0.01$; $n = 21$. In general, the closer the mean-variance fit, the smaller the difference between the coefficient estimates with the two iterative regression methods.

Sequential Sampling

Wilson (1982) presented equations for developing binomial sequential sampling plans upon which the following equations are based.

$$n_\ell = t_\alpha^2 \cdot (p - T_i)^{-2} \cdot p \cdot q \quad ,\ p < T_i \quad (5)$$

$$n_u = t_\beta^2 \cdot (p - T_i)^{-2} \cdot p \cdot q \quad ,\ p > T_i \quad (6)$$

where n_ℓ = sample size required to estimate with a given error rate (α) that the population level (p) [P(I) in equation 1] is below the control decision threshold (T) at any point in time (i); both expressed as a proportion of infested sample units (lower control decision line); and n_u = sample size required to estimate with a given error rate (β) that the population level is about the threshold (upper control decision line). Equations 5 and 6 have the same form but may differ in the error rates assigned. The further the population level is from the threshold, in either direction, the fewer the number of samples required to reach a control decision.

Control Decision Thresholds and Error Rates

At present, quantitative data do not exist for accurately assessing the control status of either of these aphid species on Brussels sprouts. We chose to take the consensus of some of the better farmers, i.e., those who regularly monitor their crop and do not treat on a calendar basis, which resulted in a proportion infested (p) threshold of 0.15 for cabbage aphid. Since green peach aphid is rarely considered a pest even at high densities, we arbitrarily chose a threshold of 0.80. Further research will eventually be necessary to refine these thresholds, although they may be sufficient until appropriate data become available.

As with the thresholds, data are lacking from which to assign realistic α and β error rates to the sampling plan. As with almost all currently used quantitative sampling plans, either sequential or otherwise, we arbitrarily chose our values ($\alpha = 0.10$, $\beta = 0.10$), although as indicated by Wilson (1982), we well realize the economic importance of using appropriate error rates as well as threshold(s).

Table 1 gives the control decision lines for both aphids. To use the sampling forms, a minimum of 10 randomly selected plants should be sampled, recording for each plant the presence or absence of each aphid species. The 10-plant minimum provides added reliability and in some cases may result in the α and β error rates being lower than designed into the sequential sampling plan. If, after 10 plants are sampled, the cumulative number of infested plants is between the no treat and treat control decision lines, then an additional sample is required. Sampling is discontinued for either aphid species when the cumulative sum reaches either of the respective control decision lines. In the event that 50 plants have been sampled and a decision has not been reached, a decision is deferred until the next sample date. Normally, sequential sampling provides a savings in sampling time of up to 65% compared with conventional enumerative fixed sample size procedures having comparable error rates (Wald 1945, Peters and Sterling 1975). In the case of binomial sequential sampling, an additional savings is realized because individual aphids do not have to be counted. Another anticipated advantage is an improvement in the timing of pesticide sprays and a reduction in the number of sprays applied.

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