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Development and Estimation of Aphid Populations Infesting Annual Winter Plantings of Strawberries in California[1]

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ABSTRACT Temporal occurrence and sampling of aphids infesting fresh market strawberries were investigated in two successive annual winter plantings in Orange County, Calif. *Chaetosiphon fragaefolii* (Cockerell) was the dominant species as well as the primary cause of contamination. *Aphis gossypii* Glover was also a contaminant, but did not reach population densities as high as *C. fragaefolii*. *Myzus persicae* (Sulzer) and *Macrosiphum euphorbiae* (Thomas) were less common and were of minor importance. Aphid densities in excess of a log (x + 1) value of 1.5 (30.6 aphids) per plant resulted in contaminated fruit. Populations of *C. fragaefolii* on the youngest or oldest leaves co-varied with total populations, but this technique was not reliable for the other species. A binomial sampling plan based on the presence or absence of aphid infestations on the oldest trifoliate leaf per plant provided an efficient and conservative estimate for determining when pesticide applications are necessary.

Aphids reach injurious levels on annual winter plantings of strawberries on an irregular basis in southern California. Although virus transmission can cause substantial losses (Chisholm and Specht 1978), the primary economic damages are due to feeding by dense aphid populations and their copius production of honeydew (Oatman and Platner 1972). Subsequent development of sooty molds on the leaves and fruit and the firm attachment of the discarded nymphal integuments result in an unmarketable product (Allen 1959). Because fresh market strawberries are packed in the field and because moisture increases disease and minimizes shelf life, water rinses are impractical. This study was designed to determine the temporal occurrence and relative dominance of the aphid species responsible for contamination, as well as documenting aphid densities at which contamination occurs. In order to improve efficiency of sampling procedures, the within-plant distribution of aphids was also examined.

Materials and Methods

Aphid infestations were monitored using whole plant counts and leaf subsamples on annual winter plantings of 'Tufts' strawberries at the University of California South Coast Field Station in Orange County, Calif. The crops were transplanted on 6 November and 2 November for the 1980–1981 and 1981–1982 plantings, respectively. Both plantings were drip irrigated and mulched with transparent plastic. In the 1980–1981 planting, the study site consisted of 15 double-row beds. Each bed was ca. 61 m long and divided into 23 sub-beds composed of 17 plants each. Weekly counts of aphids and parasitized aphids on the youngest (>1 cm leaf area) and oldest trifoliate leaves, as well as whole plant counts, were recorded from 144 plants sampled using a stratified random design. Count data were not collected on 21 May. In 1982, 118 plants per week were sampled from 12 double-row beds from 12 January to 2 March, and then 72 plants per week were assessed from 9 March to 11 May. Fruit was harvested and examined on each sampling date; fruit was considered unmarketable when cast skins, honeydew or sooty mold developing on honeydew became visually or tactilely apparent. Data were not collected on 16 March or 3 May.

Populations of the twospotted spider mite, *Tetranychus urticae* Koch, were effectively controlled with applications of cyhexatin (Plictran®) at 1.12 kg/ha on 7 January and 25 February 1981, and 15 April 1982. Cyhexatin does not significantly affect aphid populations on strawberries (Kennedy et al. 1976). No other arthropod pests occurred in sufficient numbers to require pesticide application.

Statistical Analyses

All means, standard errors and data on percent plants infested by leaf choice were generated by the Proc means procedure of the Statistical Analysis System (SAS) (Helwig and Council 1979). Coefficients of determination (r^2) for relationships between aphid numbers from whole plant counts and leaf sub-sample counts for the binomial sampling plan were determined using the Proc Corr procedure of SAS.

Results and Discussion

Sampling dates, mean weekly temperatures and ranges, plant growth, and aphid density per plant are shown in Table 1. In both the 1980–1981 and 1981–1982 plantings, aphid populations reached peak levels in March and then declined. This decline may have been partially in response to temperature, since reductions frequently occurred with increases in temperature. Also, larger populations developed in the 1981–1982 planting when temperatures were generally cooler early in the season. Declines were not due to biological control agents; parasites were not a major mortality factor (<5%) in either crop, and predators did not become common until mid-late May. Early season (Jan–Mar) populations consisted primarily of melon aphids, *Aphis gossypii* Glover, in 1980–1981, and both melon and strawberry aphids,

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Table 1. Ambient temperatures, plant growth, and aphid populations for 1980–1981 and 1981–1982 winter plantings of strawberries in Orange County, Calif.

1980–1981 Planting[a]				1981–1982 Planting[a]			
Sampling date	Mean temperature and range (°C)	Mean plant diam	Log (x + 1) aphids/plant	Sampling date	Mean temperature and range (°C)	Mean plant diam	Log (x + 1) aphids/plant
15 Jan	13.6 ± 0.9 (6.7–22.2)	16.5 ± 4.1	0.02	12 Jan	11.0 ± 5.5 (−0.6–27.8)	17.8 ± 4.6	0.44
22 Jan	13.8 ± 0.6 (6.7–22.2)	18.2 ± 4.4	0.10	19 Jan	8.6 ± 0.7 (0.0–16.1)	18.7 ± 4.3	0.70
29 Jan	11.4 ± 0.9 (3.9–19.4)	19.6 ± 4.4	0.02	26 Jan	8.0 ± 2.4 (−0.6–16.7)	20.2 ± 4.2	0.85
5 Feb	10.3 ± 1.7 (0.6–20.0)	21.0 ± 4.4	0.16	2 Feb	9.5 ± 2.4 (0.6–21.7)	19.9 ± 4.5	1.00
12 Feb	12.3 ± 1.4 (5.0–21.7)	22.1 ± 4.4	0.39	9 Feb	11.6 ± 1.3 (2.8–20.0)	22.1 ± 3.9	1.50
19 Feb	18.2 ± 1.1 (7.8–28.3)	22.9 ± 4.2	0.41	16 Feb	13.4 ± 1.9 (5.6–19.4)	22.3 ± 3.8	1.71
26 Feb	15.4 ± 4.1 (5.6–28.3)	23.8 ± 4.3	0.45	23 Feb	16.0 ± 2.0 (7.2–27.8)	22.1 ± 4.1	2.24
6 Mar	11.2 ± 0.6 (5.0–17.8)	24.8 ± 3.9	0.42	2 Mar	13.2 ± 0.9 (5.6–23.3)	25.4 ± 4.4	2.29
12 Mar	13.8 ± 1.2 (4.4–24.4)	26.7 ± 4.3	1.29	9 Mar	13.8 ± 1.7 (5.0–23.9)	26.5 ± 4.8	2.19
19 Mar	13.0 ± 0.9 (5.0–21.7)	27.8 ± 4.7	1.15	16 Mar	13.9 ± 3.0 (7.2–26.7)	—[b]	—[b]
26 Mar	13.3 ± 1.8 (6.1–22.2)	28.8 ± 5.3	1.42	23 Mar	11.2 ± 1.7 (2.8–22.2)	29.2 ± 4.9	2.09
2 Apr	12.1 ± 1.3 (3.9–21.7)	30.5 ± 4.9	0.75	30 Mar	12.0 ± 1.4 (5.0–22.2)	31.2 ± 6.5	2.03
9 Apr	14.8 ± 2.4 (5.0–30.0)	31.5 ± 5.5	0.61	6 Apr	11.0 ± 1.6 (2.8–18.3)	30.7 ± 7.1	1.86
16 Apr	15.3 ± 1.2 (7.8–21.7)	32.5 ± 5.2	0.53	13 Apr	14.0 ± 2.4 (3.9–23.3)	33.3 ± 6.5	1.40
23 Apr	14.9 ± 2.6 (6.1–25.0)	33.4 ± 5.9	0.49	20 Apr	15.3 ± 2.2 (6.7–30.0)	34.1 ± 5.9	0.62
30 Apr	18.1 ± 2.6 (9.4–32.8)	34.9 ± 7.2	0.40	27 Apr	12.2 ± 2.2 (6.7–28.9)	34.5 ± 6.4	0.16
7 May	16.2 ± 0.7 (8.9–23.9)	35.9 ± 7.3	0.38	6 May	17.1 ± 1.3 (13.3–22.2)	—[b]	—[b]
14 May	18.5 ± 1.5 (10.6–30.0)	37.6 ± 7.9	0.46	11 May	15.5 ± 1.9 (8.3–23.3)	34.2 ± 6.3	0.27
21 May	14.2 ± 1.7 (6.1–23.3)	—[b]	—[b]				
28 May	18.4 ± 1.3 (10.0–23.9)	42.8 ± 8.9	0.43				

[a]Values are means ± standard deviations; temperatures are weekly means of data collected daily. Plant diam is in cm.
[b]Data not collected.

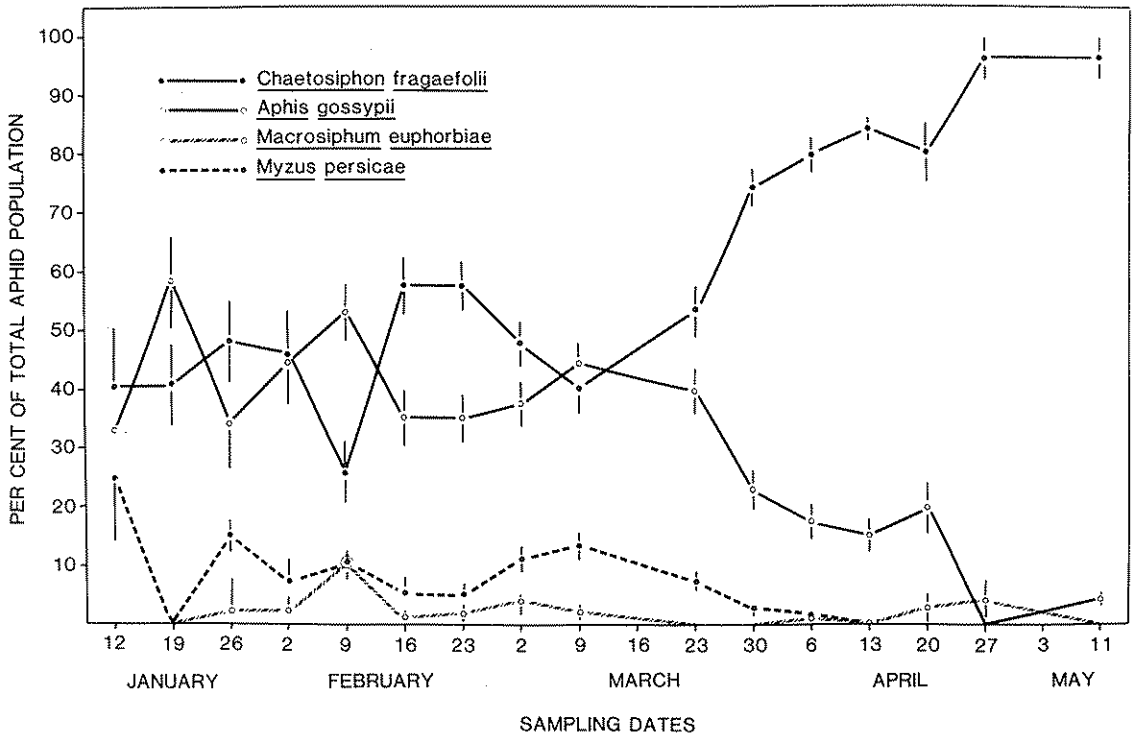

FIG. 1. Relative dominance of aphid species infesting the 1980–81 planting of fresh market strawberries in Orange County, Calif. Vertical lines on data points delineate standard errors.

Chaetosiphon fragaefolii (Cockerell), in 1981–1982 (Figs. 1 and 2). However, strawberry aphids predominated throughout the remainder of both plantings and were the most numerous aphid pest overall. Potato aphids, *Macrosiphum euphorbiae* (Thomas), and green peach aphids, *Myzus persicae* (Sulzer), were less common, and together they rarely accounted for more than 30–35% of the total aphid population. Other species were occasionally present, but did not accept strawberries as hosts and they were not included in the analyses.

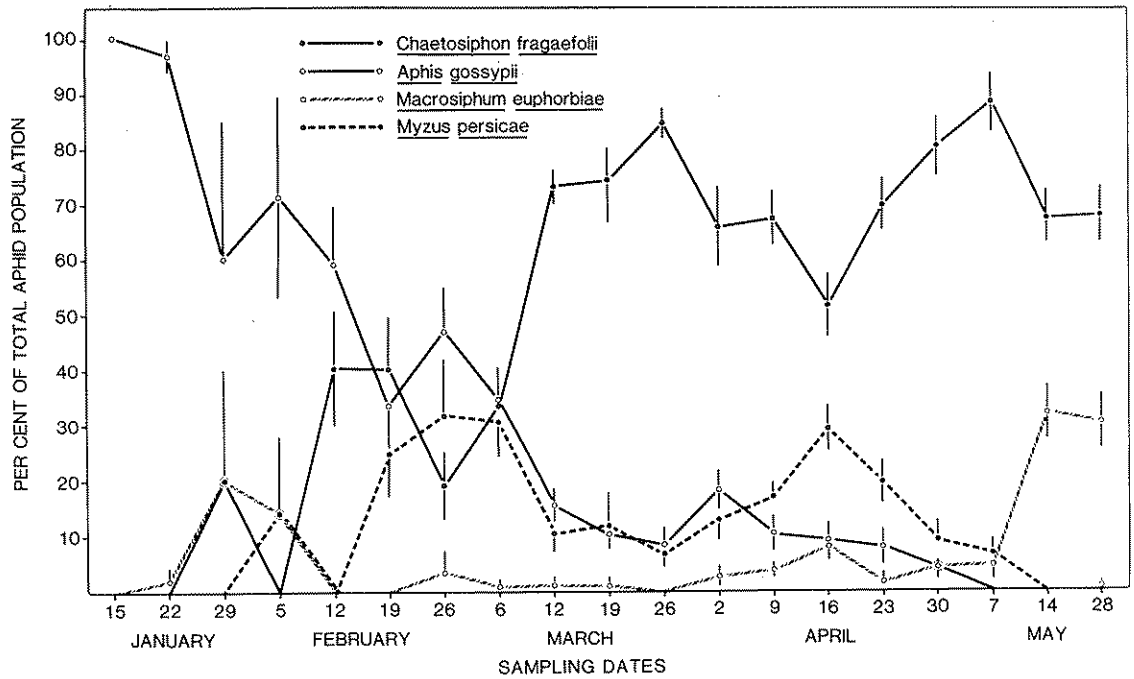

FIG. 2. Relative dominance of aphid species infesting the 1981–82 planting of fresh market strawberries in Orange County, Calif. Vertical lines on data points delineate standard errors.

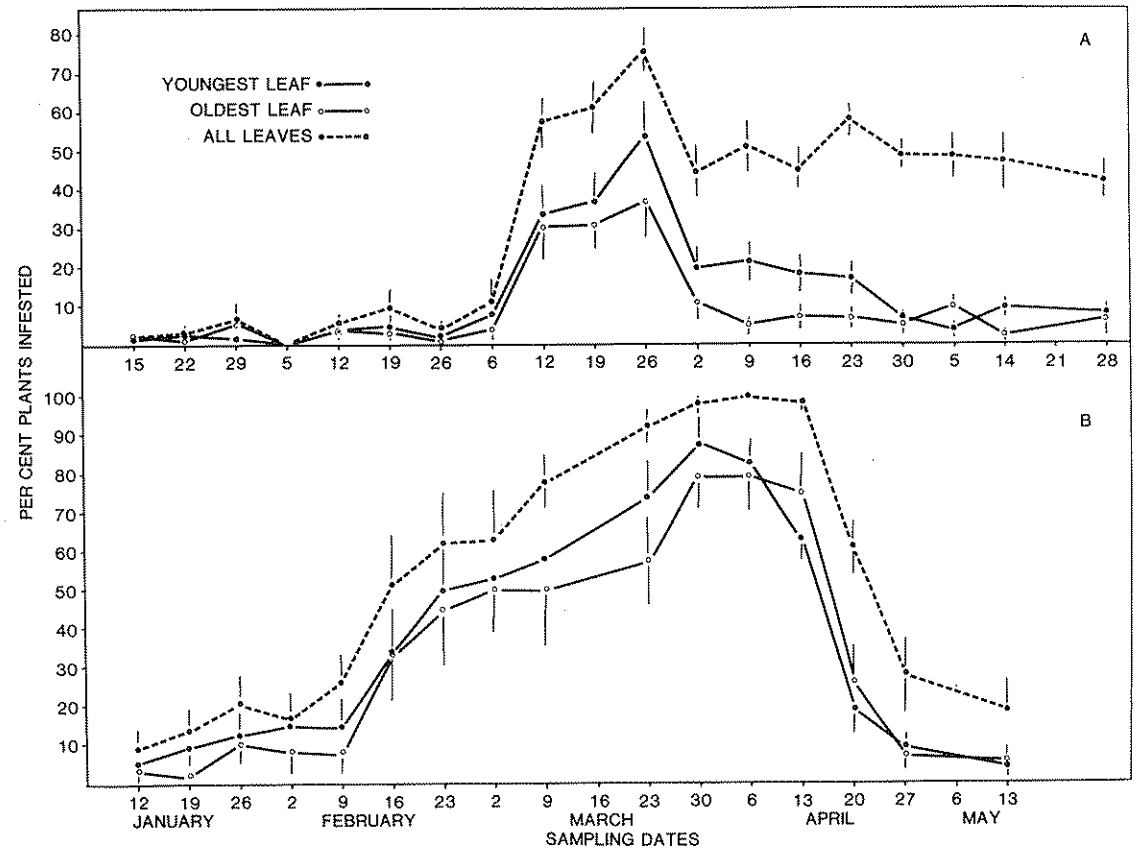

FIG. 3. Percent infested plants based on the within-plant distribution of strawberry aphids on youngest and oldest trifoliate leaves per plant as compared with whole plant counts in the 1980–81 (A) and 1981–82 (B) samplings. Vertical lines on data points delineate standard errors.

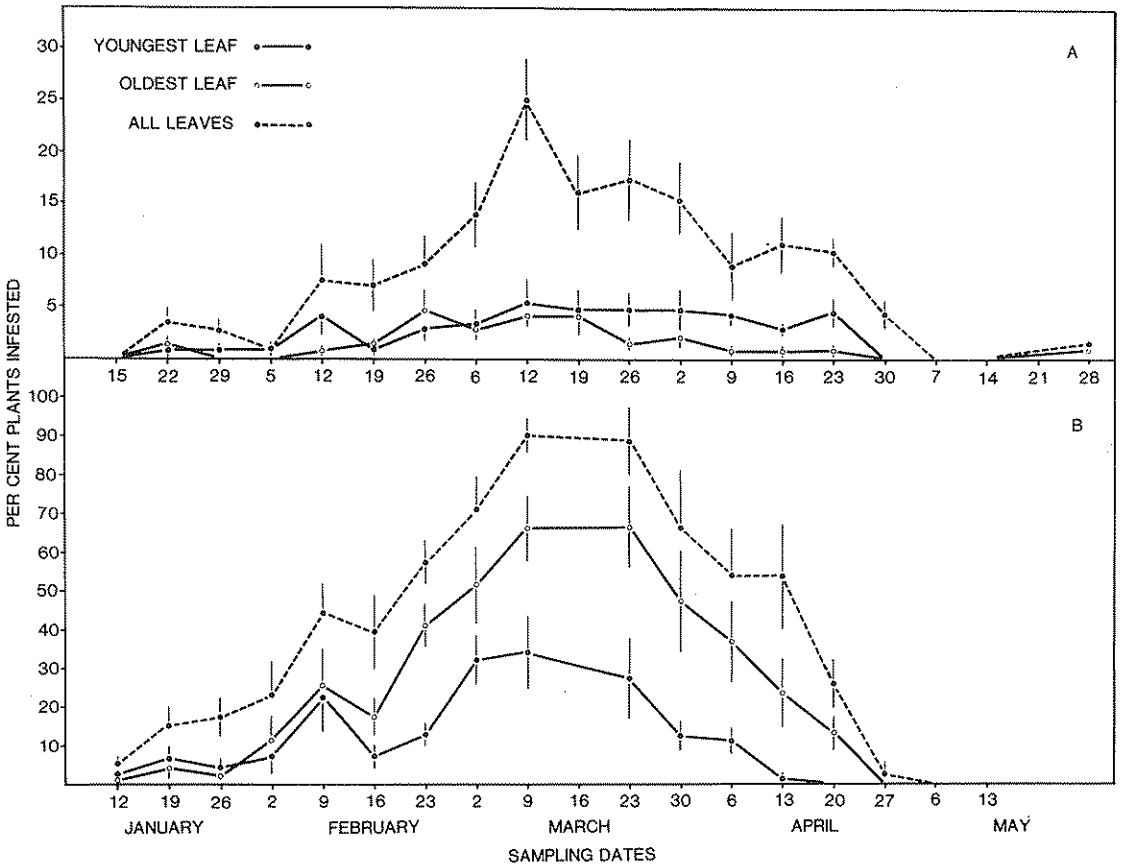

FIG. 4. Percent infested plants based on the within-plant distribution of melon aphids on youngest and oldest trifoliate leaves per plant as compared with whole plant counts in the 1980–81 (A) and 1981–82 (B) plantings. Vertical lines on data points delineate standard errors.

Table 2. Coefficients of determination (r^2) for relationships between aphid numbers from whole plant counts and leaf subsample counts on strawberry[a]

Aphid species	Location of subsample	Planting	
		1980–81	1981–82
C. fragaefolii	Youngest leaf	0.91	0.85
	Oldest leaf	0.84	0.92
A. gossypii	Youngest leaf	0.40	0.06
	Oldest leaf	0.40	0.09
M. euphorbiae	Youngest leaf	0.57	0.75
	Oldest leaf	0.90	0.55
M. persicae	Youngest leaf	NS[b]	0.35
	Oldest leaf	0.09	0.16

[a] 2,736 and 1,520 plants sampled in 1980–81 and 1981–82 plantings, respectively.
[b] NS, Not significant at the $P \leq 0.05$ level.

No contamination was found on harvested strawberries in 1980–1981, but aphids were observed on the 1981–1982 fruit when populations exceeded a log (x + 1) value of 1.50 (30.6 aphids) on 9 February. The berries became unmarketable by 16 February, when aphid density per plant increased to a log (x + 1) value averaging 1.7. Strawberry and melon aphids were generally dislodged from strawberry fruit during harvest, but discarded nymphal exuviae and honeydew remained. In spite of the decline in aphid populations, contaminated fruit were harvested until 27 April. Although some honeydew and cast skins accumulated while the fruit was immature, aphid nymphs and adults were also present on late season fruit. Thus, once aphids began to develop on berries, even the availability of unfilled niches on foliage did not promote enough migration from the fruit to provide a commercially acceptable crop.

Aphid Sampling

Strawberry aphids were reliably and efficiently sampled by subsampling either the youngest or oldest leaves (Table 2). The coefficient of determination for the oldest leaf subsample for potato aphids in the 1980–1981 planting was high ($r^2 = 0.90$), but did not prove reliable in 1981–1982. The r^2 values for all other species were either not significant at the $P \leq 0.05$ level or too low to be suitable for estimating populations.

Although leaf subsample counts were useful for monitoring populations, considerable time and effort were required to accurately determine species and count aphid numbers per leaf at densities above a log (x + 1) value of 1–1.5. Therefore, a binomial sampling plan based on

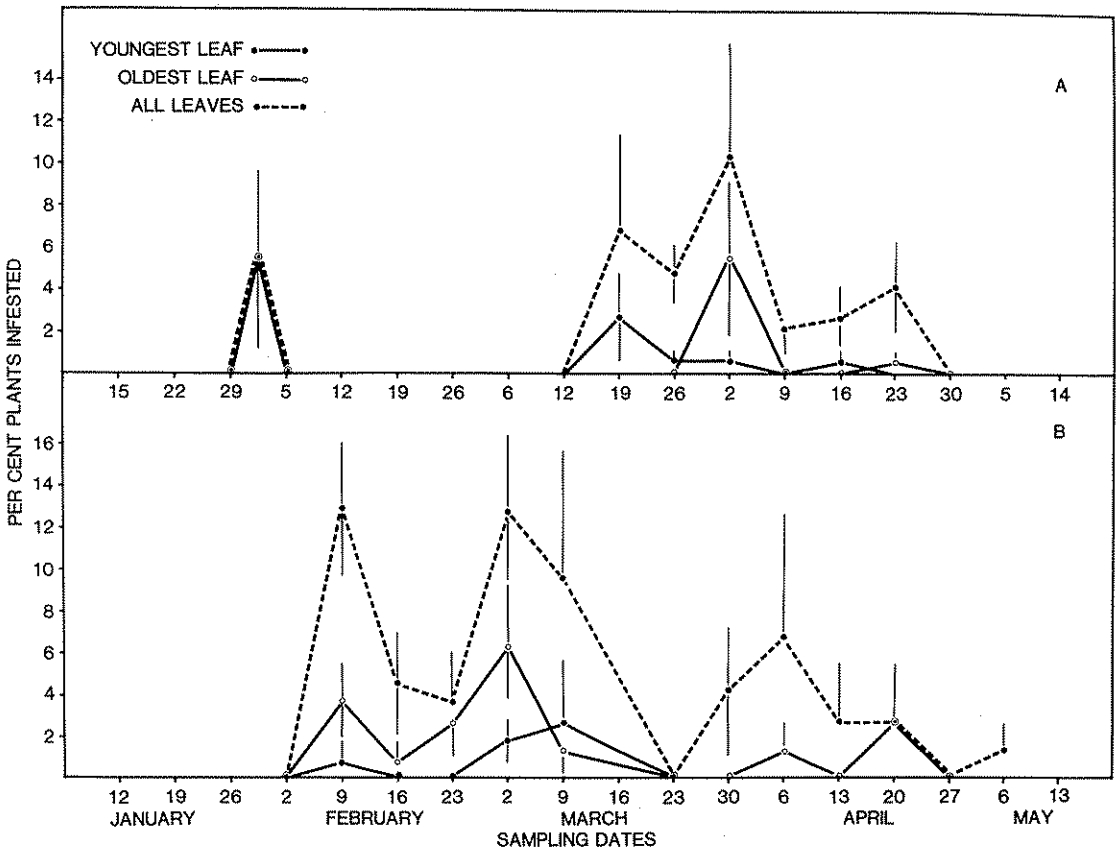

FIG. 5. Percent infested plants based on the within-plant distribution of green peach aphids on youngest and oldest trifoliate leaves per plant as compared with whole plant counts in the 1980–81 (A) and 1981–82 (B) plantings. Vertical lines on data points delineate standard errors.

presence or absence of aphids per plant was also investigated. An estimation of the need for an initial pesticide application to prevent aphid contamination was predicated on the percent plants infested as monitored by either whole plant counts or leaf subsamples. This technique proved suitable for the strawberry and melon aphids, but was of limited value for the other species.

Strawberry aphids reached population levels where the potential for contamination became high when >30% of the leaf subsamples or >50% of whole plant samples were infested; at these levels, population density exceeded a log (x + 1) value of 1.0 (Fig. 3). Because of the time savings inherent in sampling a single trifoliate leaf as opposed to an entire plant, and since *T. urticae* appeared to prefer the physiologically oldest leaves and could be sampled concurrently, subsamples from the oldest trifoliate leaves were the most practical and efficient. In addition, when melon aphids reached injurious levels in 1982, the oldest leaf per plant was more commonly infested than the youngest (Fig. 4) and provided a better estimate of the percent plants infested.

Since melon and strawberry aphids accounted for over 95% of the contamination, sampling times could be reduced by not differentiating between these species. Predominance of either melon or strawberry aphids would not affect decision levels, since the populations of these species did not co-vary significantly in either planting. Potato and green peach aphids could not be effectively subsampled using this technique (Figs. 5–6). However, inclusion of these species in the sampling estimates of percent infestation would simplify sampling by eliminating problems associated with identification and would increase the probability of a treatment decision, thereby providing a conservative basis for the treatment decision.

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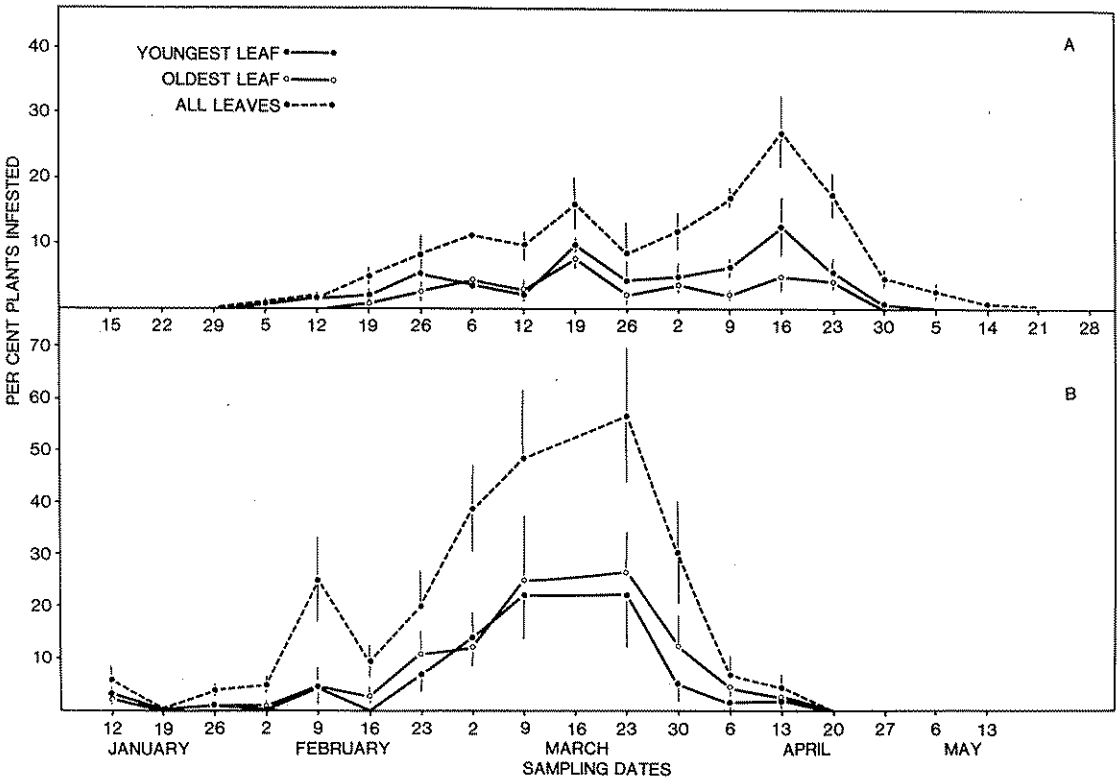

FIG. 6. Percent infested plants based on the within-plant distribution of potato aphids on youngest and oldest trifoliate leaves per plant as compared with whole plant counts in the 1980–81 (A) and 1981–82 (B) plantings. Vertical lines on data points delineate standard errors.

REFERENCES CITED

Allen, W. W. 1959. Strawberry pests in California. Calif. Agric. Exp. Stn. Ext. Serv. Circ. 484: 1–40.

Chisholm, D., and H. B. Specht. 1978. Residues and control of aphids on strawberries with banded surface applications of Disulfoton. J. Econ. Entomol. 71: 469–472.

Helwig, J. T., and K. A. Council [eds.]. 1979. SAS User's Guide. 1979 edition. SAS Institute Inc. Cary, N.C. 494 pp.

Kennedy, G. G., E. R. Oatman, and V. Voth. 1976. Suitability of Plictran® and Pirimor® for use in a pest management program on strawberries in southern California. J. Econ. Entomol. 69: 269–272.

Oatman, E. R., and G. R. Platner. 1972. An ecological study of aphids on strawberry in southern California. Environ. Entomol. 1: 339–343.