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Aphid (Homoptera: Aphididae) Population Dynamics on Broccoli in an Interior Valley of California[1]

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ABSTRACT

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Myzus persicae (Sulzer) was the most abundant aphid species encountered in fall and winter plantings of broccoli in Riverside County, Calif., during 1980 to 1981. *Brevicoryne brassicae* L. populations were smaller, but this species was of greater importance as a contaminant of broccoli. Aphid migration and density per plant were lower in the winter crop, but the potential for contamination was higher. Aphid species segregated by leaf choice, with *M. persicae* preferring the oldest leaves and *B. brassicae* the youngest. Plant age and growth affected aphid distribution. Sampling procedures based on 10-plant samples and leaf subsamples provided reliable estimates of aphid populations and may be suitable for scouting programs for aphids on broccoli.

California produces in excess of 95% of the broccoli, *Brassica oleraceae* L., Botrytis group, grown commercially in the United States (Anonymous 1979). Although the bulk of the crop is planted in coastal regions, two desert counties (Riverside and Imperial) harvested over $5.5 million worth of broccoli in 1978 (Johnson and Claxton 1978). Unfortunately, little research is available on the insect pests of broccoli in California, and most studies have concentrated on crops grown in the coastal areas. Wyman and Oatman (1977) reported economic injury levels for lepidopterous larvae on broccoli, Kennedy and Oatman (1976) investigated selective pesticides for insect control in Orange County, and Trumble (1982a,b) studied temporal occurrences, distribution, and sampling of aphids attacking broccoli grown along California's south coast. Each of these studies examined the effect of insect occurrence and density during only the preheading stage, since control of established insect populations, particularly aphids, is difficult once head formation begins. My objectives were to investigate aphid population dynamics and to develop sampling procedures for aphid species attacking broccoli in an interior desert valley of California.

Materials and Methods

Experiments were conducted in two successive 0.4-ha plantings of 'DeCicco' broccoli at the CRC Agricultural Operations Center in Riverside County, Calif. Both plantings were direct-seeded by using a Ventura planter in single-row beds and were furrow irrigated until harvest. Row centers were 0.76 m apart. The fall planting was seeded 9 September 1980, thinned to 20-cm spacings on 3 October, and harvested 1 and 2 December. The winter crop was planted 3 December 1980 and thinned on 10 January 1981, but was not harvested because of bolting due to unusually warm weather during the heading stage. Maximum and minimum temperatures as well as rainfall were monitored on a daily basis.

Four treatments were evaluated: unsprayed plots; plots treated when aphid populations reached 5 to 10 per plant; plots sprayed when pest density exceeded 100 per plant; and plots treated only after head formation began. Each

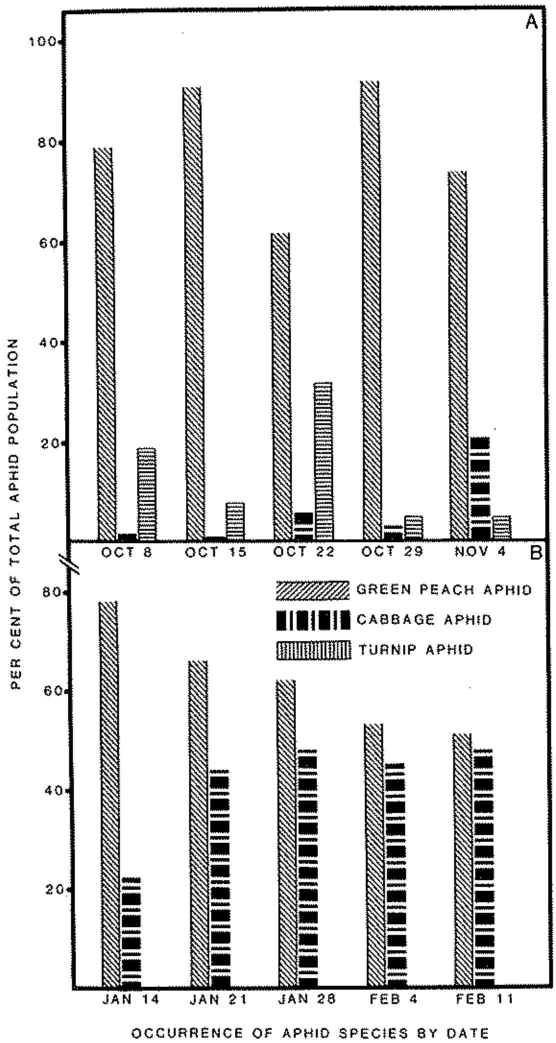

FIG. 1.—Relative dominance of aphid species occurring on fall and winter broccoli in Riverside County, Calif., between 1980 and 1981. (A) fall planting; (B) winter planting.

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Table 1.–Plant growth data, ambient temperatures, and sampling information for aphids associated with fall and winter broccoli in an interior valley of California

Planting	Sampling date[a]	No. of plants sampled	$\bar{x}$ Plant height (cm)[b]	$\bar{x}$ No. of leaves/plant	$\bar{x}$ Weekly temp and range (°C)	log (X + 1) aphids/plant	CV[c]
Fall	8 Oct.	240	12.7 ± 0.8	5.5 ± 0.9	24.8 (12.8–43.8)	1.15 ± 0.23	20.9
	15 Oct.	180	16.2 ± 1.31	8.2 ± 1.0	20.7 (6.1–36.1)	1.24 ± 0.24	19.1
	22 Oct.	180	22.9 ± 1.0	13.0 ± 1.2	16.1 (5.6–29.4)	1.62 ± 0.25	15.1
	29 Oct.	120	30.7 ± 1.2	18.4 ± 2.0	17.8 (5.0–30.6)	1.80 ± 0.19	10.6
	4 Sept.	120	34.6 ± 1.3	23.7 ± 3.4	18.2 (3.3–33.3)	2.07 ± 0.20	9.1
Winter	14 Jan.	240	6.7 ± 1.1	5.8 ± 0.5	14.8 (6.1–24.4)	1.02 ± 0.13	13.2
	21 Jan.	180	11.3 ± 0.7	6.8 ± 0.5	13.3 (−0.6–23.9)	1.02 ± 0.12	11.8
	28 Jan.	180	14.3 ± 1.7	8.5 ± 0.9	12.6 (−0.6–25.0)	0.77 ± 0.27	35.1
	4 Feb.	180	17.0 ± 1.2	10.1 ± 0.5	9.7 (0.6–23.9)	0.84 ± 0.17	20.2
	11 Feb.	180	20.6 ± 0.6	12.9 ± 1.7	13.9 (0.0–28.9)	0.90 ± 0.22	24.7

[a]Samples taken between thinning and heading.
[b]Values indicate means ± SD.
[c]CV = Coefficient of variation.

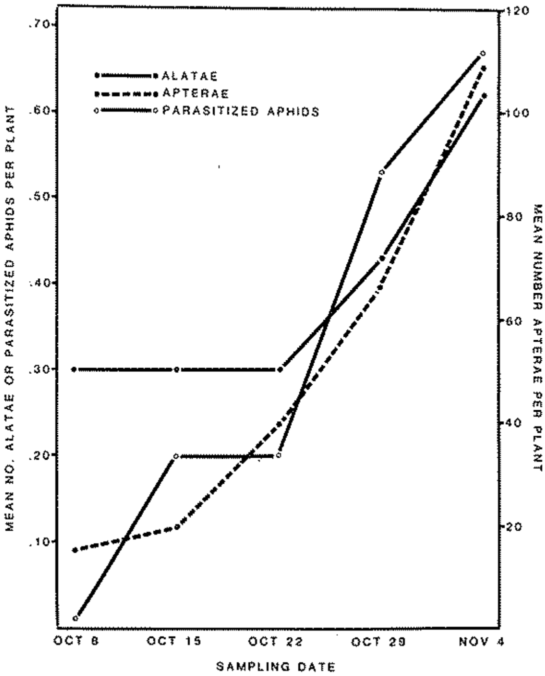

FIG. 2.—Occurrence of alatae, apterae, and parasitized aphids on fall broccoli between thinning and head formation in Riverside County, Calif., 1980 to 1981.

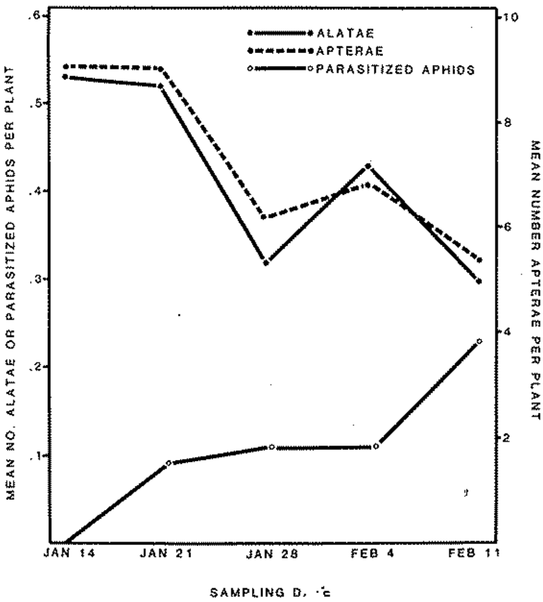

FIG. 3.—Occurrence of alatae, apterae, and parasitized aphids on winter broccoli between thinning and head formation in Riverside County, Calif., 1980 to 1981.

plot was 20 m long and six rows wide. Treatments were replicated six times, and plots were arranged in a randomized complete block design with at least 5 m of untreated rows separating each plot. A buffer of 5 m of

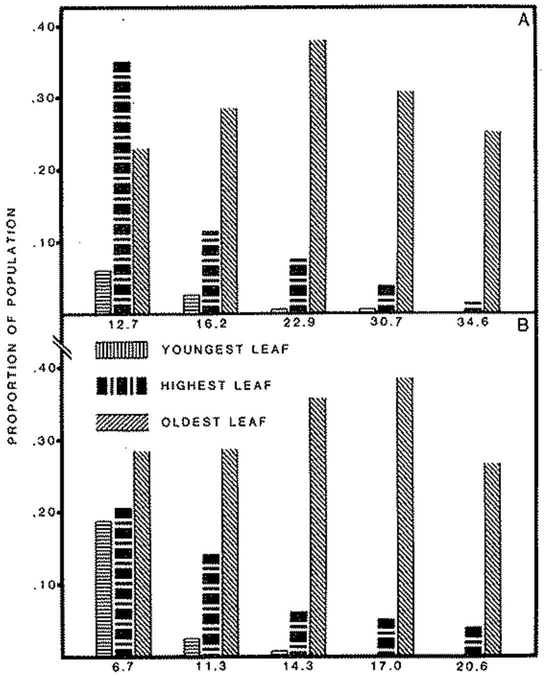

FIG. 4.—Within-plant distribution of *M. persicae* on fall and winter broccoli plantings in Riverside County, Calif., between 1980 and 1981. (A) Fall planting; (B) winter planting.

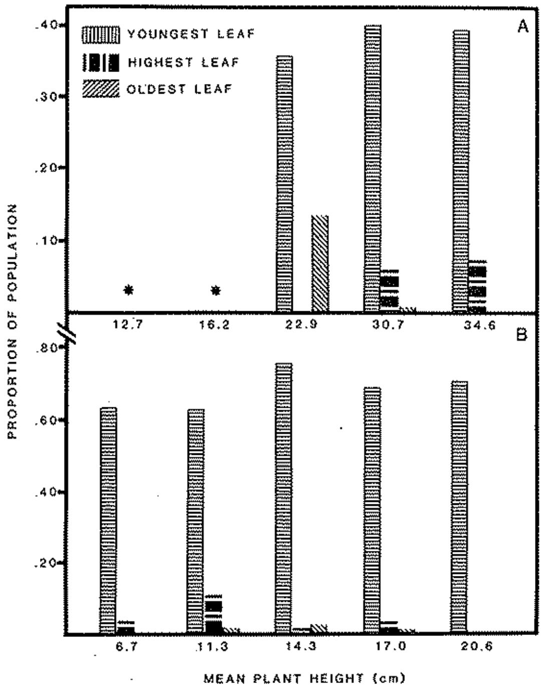

FIG. 5.—Within-plant distribution of *B. brassicae* on fall and winter broccoli plantings in Riverside County, Calif., 1980 to 1981. (A) Fall planting; (B) winter planting. (Asterisks refer to sampling dates where fewer than 25 *B. brassicae* were found.)

broccoli and 10 m of bare earth surrounded each experimental planting to help reduce potential "edge effects" or influence of windbreaks as reported by Lewis (1969).

Ten plants from the center four rows of each plot were sampled weekly for aphids from thinning until head formation. Plants were selected by using a stratified random sampling plan, and each was assessed for the numbers of alatae and apterae occurring on the upper and lower surfaces of all leaves. Aphids found on the youngest (>1.0 cm leaf area), highest (mature), and oldest leaves were recorded separately. Aphid species on 60 plants in the six untreated control plots were counted individually to determine temporal occurrence and dominance on all dates, except 8 and 15 October when 40 plants were examined. Data listed in Tables 1 and 2 refer to aphid counts from all treatments which had not had pesticide applied before the specified sampling date.

Pirimicarb (0.28 kg of AI/ha) and *Bacillus thuringiensis* Berliner (1.12 kg/ha) were applied to reduce aphid populations in the yield tests and to minimize damage caused by lepidopterous larvae, respectively. Both pesticides were applied to the fall planting on 9, 16, 23, and 30 October, and the winter planting was treated on 16 January. Aphid densities of 5 to 10 per plant were treated with Pirimicarb on each date listed; aphid densities of 100 per plant were sprayed on 30 October. Methomyl, a broad-spectrum pesticide used commercially, was applied at 1.0 kg/ha after head formation in all treatments except the control to reduce populations of lepidopterous larvae and to help prevent contamination. Applications were made on 12, 19, and 26 November to the fall planting, and on 18 February 1981 to the winter crop. All pesticides were applied by a tractor-mounted row crop sprayer with one to five hollow cone nozzles per row, depending on plant height. Carrier (H_2O) ranged from 282 to 934 liters per ha, and nozzle pressure varied from 4.2 to 7.1 kg/cm^2 as plant height and foliage density increased. Biofilm (0.04%) was included in all sprays as a spreader sticker.

Yields were measured by weighing 20 to 50 heads per replicate. Leaves were stripped off, and stalks were trimmed to 10 cm before weighing. After weighing, the heads were examined for insect contamination.

Statistical Analysis

Aphid counts listed in Table 1 were normalized by using the log (X + 1) transformation suggested by Hayman and Lowe (1961) and Taylor (1970). Normality was confirmed for data from each sampling date by the Proc Univariate Normal procedure of the statistical analysis system (SAS) (Helwig and Council 1979). Means and SDs shown in Table 2, and the coefficients of variation presented in Table 1 were computed by the Proc Means procedure of SAS. Comparisons of aphid counts from upper and lower leaf surfaces were made by the Student t test at the $P < 0.05$ level. Yield data were compared between treated and untreated plots by analysis of variance (ANOVA) with the Proc ANOVA procedure of SAS. Coefficients of determination (r^2) shown in Table

Table 2.—Aphid distribution within broccoli plants for two successive plantings in Riverside County, Calif., 1980 to 1981

		No. of aphids[a]							
		Upper leaf surface				Lower leaf surface			
Planting	Sampling date	Youngest	Highest	Oldest	Total	Youngest	Highest	Oldest	Total
Fall	8 Oct.	0 ± 0	0.15 ± 0.10	0.01 ± 0.04	0.03 ± 0.05a	0.40 ± 0.45	6.78 ± 4.89	2.12 ± 2.01	15.92 ± 8.17b
	15 Oct.	0.05 ± 0.08	0 ± 0	0.08 ± 0.09	0.55 ± 0.70a	0.48 ± 0.55	1.95 ± 0.92	5.50 ± 2.89	18.97 ± 8.96b
	22 Oct.	0.02 ± 0.04	0.03 ± 0.05	0.07 ± 0.12	2.13 ± 2.40a	0.77 ± 0.88	2.05 ± 2.22	8.03 ± 6.37	37.88 ± 30.17b
	29 Oct.	0 ± 0	0.03 ± 0.05	0.07 ± 0.10	2.65 ± 2.58a	1.22 ± 1.54	2.28 ± 2.13	20.93 ± 7.99	64.25 ± 22.06b
	4 Nov.	0.03 ± 0.05	0.02 ± 0.04	0.13 ± 0.12	21.74 ± 33.24a	1.47 ± 1.33	9.52 ± 18.03	23.43 ± 12.33	82.40 ± 44.45a
Winter	14 Jan.	0.15 ± 0.12	0.17 ± 0.15	0.03 ± 0.05	2.77 ± 0.55a	2.88 ± 1.34	1.75 ± 0.50	2.33 ± 1.10	8.18 ± 3.00b
	21 Jan.	0.08 ± 0.09	0.12 ± 0.08	0.08 ± 0.10	3.07 ± 0.63a	2.52 ± 1.03	1.38 ± 0.59	2.12 ± 0.89	7.72 ± 2.56b
	28 Jan.	0.03 ± 0.05	0.02 ± 0.04	0.08 ± 0.04	2.13 ± 1.03a	1.92 ± 0.76	0.28 ± 0.32	1.53 ± 1.03	4.63 ± 2.80a
	4 Feb.	0 ± 0	0.18 ± 0.12	0 ± 0	3.02 ± 1.09a	2.30 ± 0.51	0.15 ± 0.14	1.47 ± 0.76	4.33 ± 1.60a
	11 Feb.	0.02 ± 0.04	0.02 ± 0.04	0.08 ± 0.10	3.93 ± 2.80a	2.93 ± 2.11	0.15 ± 0.32	1.13 ± 0.51	4.77 ± 2.25a

[a] $\bar{x}$ ± SD based on replicates of 10 plants; numbers in rows followed by the same letter are not significantly different at $P < 0.05$ level (Student's t test); sample sizes on each date are the same as listed in Table 1.

Table 3.—Coefficients of determination (r^2) for relationships between aphid numbers from wholeplant counts and leaf subsample counts on broccoli[a]

	Planting season	
Location of subsample	Fall	Winter
Youngest leaf	0.82	0.72
Highest leaf	0.33	NS[b]
Oldest leaf	0.92	0.56

[a]Analyzed in replicates of 10 plants; 840 and 960 plants sampled in the fall and winter plantings, respectively.
[b]NS, Not significant at $P < 0.05$ level.

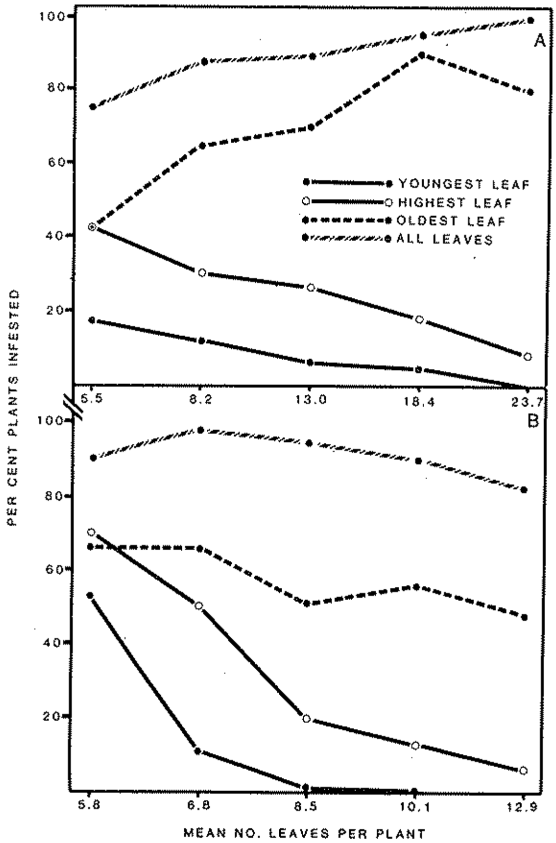

FIG. 6.—Percentage of plants infested by *M. persicae* in two successive broccoli plantings in Riverside County, Calif., 1980 to 1981. (A) Fall planting; (B) winter planting.

3 were computed with the Proc GLM procedure of SAS; whole-plant counts were independent variables, and leaf subsample counts were dependent variables.

Results and Discussion

Occurrence and Economic Injury Level Studies

The green peach aphid (GPA), *Myzus persicae* (Sulzer), was the dominant aphid species encountered throughout this study. GPA accounted for 63 to 90% and 52 to 78%

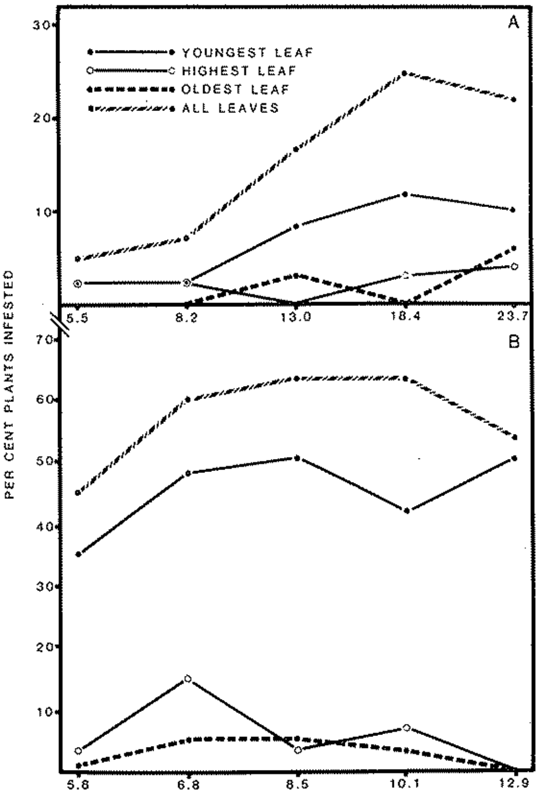

FIG. 7.—Percentage of plants infested by *B. brassicae* in two successive broccoli plantings in Riverside County, Calif., between 1980 and 1981. (A) Fall planting, (B) winter planting.

of the total aphids observed in the fall and winter crops, respectively (Fig. 1). The turnip aphid, *Hyadaphis erysimi* (Kaltenbach), occurred sporadically in the fall crop, reaching a peak of 32% of the total aphid population on 22 October. However, since turnip aphids were not a contaminant in the heads harvested from the fall planting and their populations did not exceed 0.25% of the aphids occurring in the winter crop, this species was considered a minor pest.

The cabbage aphid, *Brevicoryne brassicae* (L.), developed relatively small populations in comparison to GPA or *H. erysimi* in the fall planting but was the primary contaminant of broccoli heads. This information concurs with reports of the importance of *B. brassicae* as a contaminant of broccoli grown in the coastal regions of California (Kennedy and Oatman 1976, Trumble 1982a). As temperatures dropped during the winter planting, *B. brassicae* populations increased to 48% of the total aphid population and the potential for contamination increased.

Potato aphids, *Macrosiphum euphorbiae* (Thomas), were rarely observed and were not important as contaminants. Similar observations were reported for *M. euphorbiae* attacking broccoli in coastal California (Trumble 1982a).

Aphid colonization and population growth were slower in the winter than in the fall (Table 1). Temperatures during the primary morning flight periods were low (2 to 4°C) during the winter planting, and rapid temperature increases characteristic of southern California's deserts were often associated with an increase in wind velocity to levels which reduce initiation and duration of migratory flights (Dry and Taylor 1970). Population growth during the winter planting was further reduced by cool temperatures that increased developmental times and decreased reproductive rates.

Figures 2 and 3 show the appearance of alatae and the subsequent production of apterae for the fall and winter crops, respectively. In the fall crop, large numbers of apterous, viviparous females were larviposited which, when reproductively mature, rapidly increased aphid density. Populations of apterous aphids then rose to 110 per plant when migrant density was still only ca. 0.6 per plant. In contrast, both alate and apterous aphid populations declined after thinning in the winter planting (Fig. 3). Cool temperatures and more than 5 cm of rain during the last 2 weeks of January reduced aphid populations.

Parasites were ineffective in suppressing aphid density and did not parasitize more than 5% of the aphids on any sampling date in either planting. Parasite and hyperparasite species were not recorded, but information on species composition and occurrence of parasites and hyperparasites associated with the cabbage aphid in southern California were reported by Oatman and Platner (1973). Adult and larval Coccinellids as well as syrphid larvae were occasionally observed attacking aphid colonies in the fall crop, but predators were unable to reduce aphid contamination to commercially acceptable levels in the control plots. Way et al. (1969) reported similar results on the ineffectiveness of biological control agents for controlling pests of brussel sprouts.

Economic injury levels resulting from the complex of aphid species on broccoli could not be determined for yields. No significant differences were found between untreated control plots and all other treatments, including plots which were treated weekly with pirimicarb whenever aphid populations reached 5 to 10 per plant. Therefore, insecticide applications for aphid densities of up to 100 per plant were not justified by yield loss. However, population suppression necessary to prevent contamination may require pesticide application before head formation when aphid density is below economic thresholds based on yield. Contamination was less than 0.5% in all treatments except the control, where aphids infested 19.5% of the harvested heads. Aphid populations were reduced by at least 95% after each application of pirimicarb. Unusually, warm weather during the heading stage of the winter crop caused bolting, and comparative yield data could not be collected.

Aphid Distribution

Figure 4 shows the within-plant distribution of GPA. GPA preferred the oldest leaves to the youngest and highest leaves on nearly all sampling dates, but segregation by leaf choice was most obvious on taller plants where physiological differences between leaves were greater. These results concur with reports of GPA selecting the oldest leaves of brussel sprouts (Dunn and Kempton 1971). GPA preferentially colonized the highest leaves before the youngest leaves. This information agrees with previous studies of leaf choice by aphids on broccoli (Trumble 1982b) but conflicts with data presented by Kennedy et al. (1950) showing that the young leaves of sugar beets and spindle trees were more attractive to GPA than mature leaves.

In contrast to GPA, *B. brassicae* selectively colonized the youngest leaves before the oldest or highest leaves (Fig. 5). This observation corroborates reports by van Emden and Bashford (1969) on the distribution of GPA and *B. brassicae* on brussel sprouts and also supports statements by Kennedy (1958) and Mittler (1958) that optimum nutrition for aphids is available from young and old leaves as sites of protein synthesis and breakdown, respectively. Lower proportions of *B. brassicae* populations found on the youngest leaf per plant in the fall as compared with the winter appeared to be in response to the production of numerous small axial leaves in the fall planting which were attractive to alates. Broccoli plants in the winter crop produced fewer axial leaves, and most of these developed after head formation began.

The distribution of the aphid complex on the upper and lower leaf surfaces indicated a significant preference ($P < 0.05$) for the undersides of leaves when *B. brassicae* populations were small. Statistical separation by leaf surface was not evident when *B. brassicae* density increased to above 20% of the total aphid population. Similar results were reported for the aphid complex attacking broccoli grown in coastal California (Trumble 1982b).

Analysis of leaf choice between the youngest, highest, and oldest leaves in both plantings determined that the oldest leaf was the most heavily infested (Table 2). Aphid counts from the highest leaves were generally intermediate between the youngest and oldest leaves in the fall planting but were usually the lowest in the winter crop. Data from the winter crop differ from observations on leaf choice reported by Trumble (1982b), where the highest leaf was preferred to the youngest. The shift in leaf choice probably was due to more distinct niche separation of species resulting from smaller aphid populations and fewer species occurring on broccoli in Riverside County as compared with coastal California.

Sampling Aphid Populations

Variation in aphid counts generally decreased with increasing aphid density. Therefore, larger populations would require fewer samples to produce a statistically acceptable estimate of aphid density (within 10 to 20% error). This concurs with data reported by Trumble (1982a). However, this sampling technique was tedious and labor intensive and would not be suitable for scouting programs if aphid populations were small or the acreage was large.

Aphid density can be reliably and efficiently estimated by using leaf subsample counts as opposed to time-consuming whole-plant counts (Table 3). When GPA was dominant in the fall planting, subsample counts of aphids from the oldest leaf per plant were predictively useful ($r^2 = 0.92$) for estimating total aphid population per plant. In the winter planting, where GPA and *B. brassicae* codominated, leaf subsample counts from the youngest leaf per plant could be used to estimate aphid density ($r^2 = 0.72$). The leaf subsample technique may be most useful for assessing GPA populations on young plants susceptible to physical damage by large aphid populations and for early detection of *B. brassicae* before head formation and contamination.

Subsampling specific leaves would also improve sampling proficiency by increasing the efficiency of locating aphid infestations (Fig. 6 and 7). In both plantings, more plants were infested by GPA on the oldest leaves than the highest or youngest. Similarly, more plants supported *B. brassicae* populations on the youngest rather than the highest or oldest leaves. Aphid separation by leaf choice was lowest for both species when plants were small and physiological differences between leaves were minor. Therefore, when plants have few leaves (< six per plant), the more accurate whole-plant samples would be only slightly more time-consuming than subsampling specific leaves.

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