Experimental plot of mixed broccoli cultivars.

# Mixing broccoli cultivars reduces cabbage aphid numbers

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***The reason isn't clear, but physical differences between cultivars may play a part.***

Opportunistic pathogens and insect pests with high adaptability and a wide genetic variability have become an increasing problem in modern, genetically uniform, agricultural systems. Some plant pathologists have recognized this situation and have suggested increasing genetic diversity in crop fields to reduce epidemic outbreaks. Among the available options, mixing cultivars of different resistances (variety mixtures or multilines) has been found to reduce disease levels (especially rusts) in several grain production systems.

The use of this strategy in insect control has been virtually unexplored, although some entomologists have examined it as a way of deploying resistant germplasm to lower the rate at which insect pests adapt to a given resistant cultivar.

Despite the biological differences between pathogens and insects, we believe some elements of the theory of pathogen epidemiology in variety mixtures could be used to explain insect responses in fields composed of mixed varieties. The presence of resistant plants impedes pathogen spread by increasing the separation between susceptible plants. It is possible that, depending on the degree to which insect pests discriminate between resistant and susceptible cultivars, the intensity of insect attack could be reduced in a field with a wide array of crop cultivars.

We studied the effects of varietal diversity in the field on the population response of the cabbage aphid, *Brevicoryne brassicae* (L.). Stands of broccoli, *Brassica oleracea botrytis* (L.), composed of a single cultivar or mixed cultivars were used to determine how aphid population densities were affected by variety mixtures, variety proportions, planting arrangements, and planting times of different broccoli varieties. Our main objective was to test whether increased cultivar diversity in crops reduces pest populations.

## Methods

The study consisted of three experiments conducted during 1985-86 at the University of California, Berkeley's Gill Tract in Albany. All plots (5 by 6 meters each [about 16 by 20 feet]) were planted with 80 greenhouse-grown broccoli plants (12 cm [about 5 inches] tall). Treatments were replicated either three or five times. Each plot had eight rows with 10 plants each, 60 cm (24 inches) between rows, and 50 cm (20 inches) between plants. A 1-meter space between plots was kept free of vegetation by frequent rototilling. Broccoli varieties used were Asgrow's Futura (var. A), Orion (var. B), Apollo (var. C), and Gem (var. D). This selection was based on the varieties' suitability to environmental conditions at Albany. We had no information in advance about their resistance to cabbage aphid.

We estimated densities of winged and wingless aphids on the plants weekly by counting the numbers on five randomly selected plants of each variety in each plot for eight weeks. The number of aphid mummies, and height and number of leaves of each broccoli plant were also recorded. At harvest time, all sampled plants were cut at soil level to estimate total number of aphids, mummies, plant biomass, and fresh weight of broccoli heads. Plant height and biomass were measured throughout the experiment. We performed statistical analyses to compare aphid densities between treatments, and to separate significantly different densities resulting from varying cultivar diversity in the field.

## Mixed varieties

The first experiment was designed to test effects of a mixture of four broccoli varieties on cabbage aphid densities. Each treatment was replicated five times. The mixture consisted of 20 plants each of varieties A, B, C, and D and was compared with a broccoli planting composed only of variety A. The experiment was conducted in the spring and fall of 1985.

Overall, aphid populations were about eight times higher in the spring than in the fall plantings. During the spring, single-variety (monoculture) and mixed-variety treatments had similar total numbers of aphids per plot (fig. 1A). During the fall, however, this trend changed, and monoculture plots had significantly higher aphid counts than did the mixed plot (fig. 1B).

In the fall experiment, average aphid densities per plant on variety A were initially similar in both treatments, but became significantly higher in the monocultures after the sixth week. Within the mixed variety plots, aphids concentrated more on varieties A, B, and C (fig. 2). (In figure 2, each horizontal area represents the proportion of aphids on each variety in relation to the total aphid population per plot.) Variety D had a much smaller aphid density than did the other three varieties. This variety preference remained consistent throughout the season. Taller plants (var. A and B) tended to have higher aphid populations (table 1), reflecting a highly significant correlation between the height of plants within each plot and the total number of aphids on each plant.

## Variety proportions

In the second experiment, randomly assigned plantings had different proportions of the varieties (table 2).

Plots consisting of 100 percent variety A had considerably higher aphid numbers per unit area than did the other three plantings. Aphid numbers per plot decreased as the proportion of variety A de-

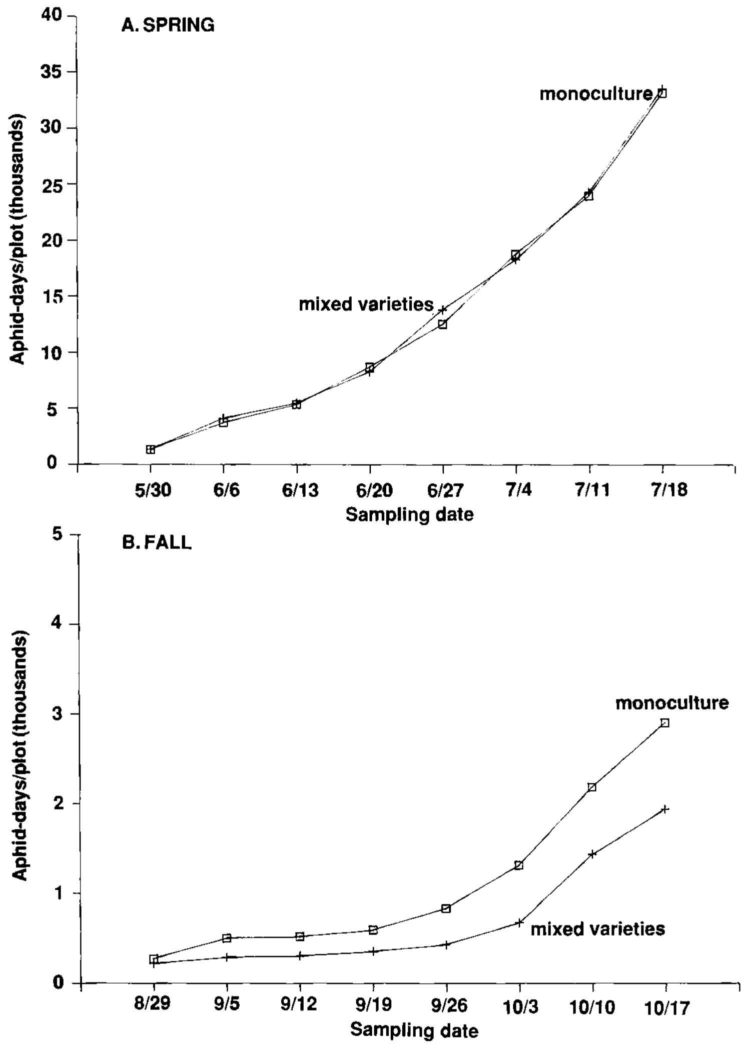


Fig. 1. Total accumulated numbers of cabbage aphids per plot were similar in spring broccoli plantings (A), but in fall plantings (B) mixed-variety plots had fewer aphids than did monoculture plots. Overall, spring populations were eight times higher than in fall.

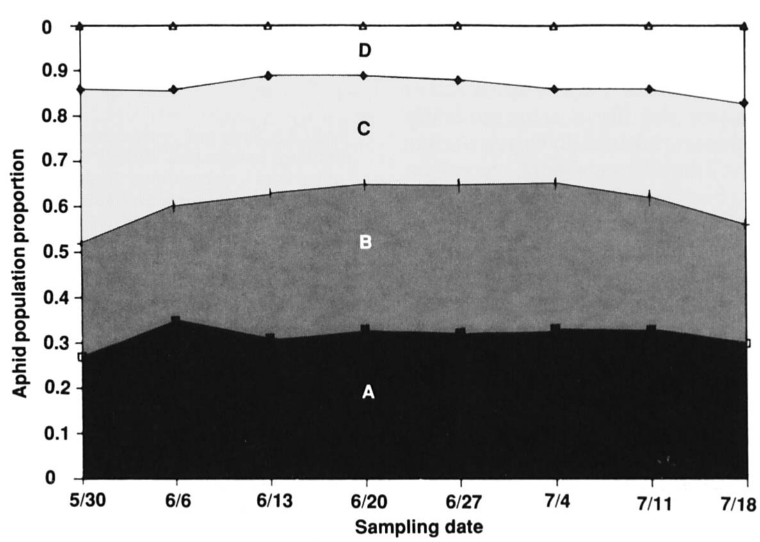


Fig. 2. Proportion of cabbage aphid on each broccoli variety (A - D) in relation to total aphid population in the mixed-variety plot. In mixtures, aphids concentrated on varieties A, B, and C.

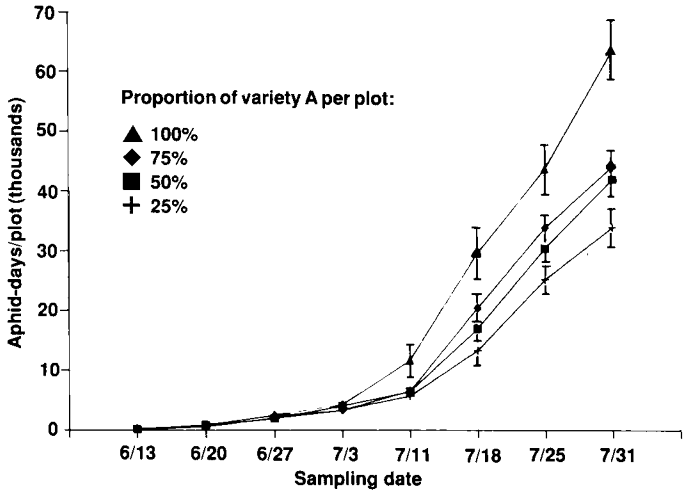


Fig. 3. Illustrating the effect of varietal diversity, cabbage aphid numbers per plot were highest in plots consisting of 100 percent broccoli variety A. Aphid numbers decreased as the proportion of variety A decreased in relation to the other three broccoli varieties.

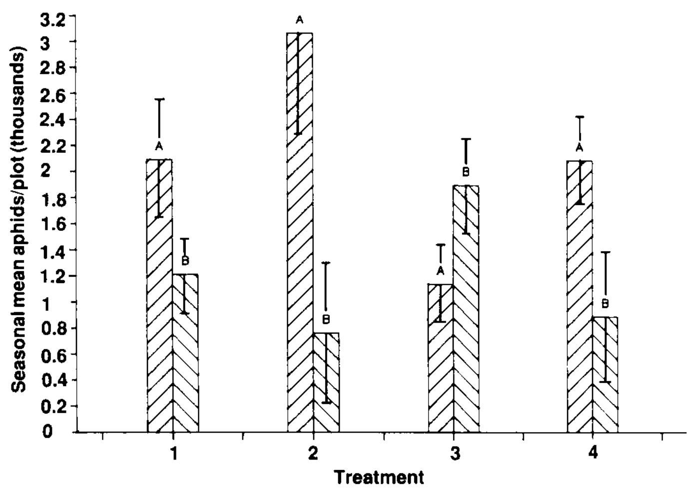


Fig. 4. Seasonal average number of aphids on varieties A ('Futura') and B ('Orion') under various planting arrangements and times: A and B planted simultaneously, with B as border (1) or center (2) rows; or B planted 15 days before A, with B as border (3) or center (4) rows.

creased (fig. 3). Within the mixed-variety plots, the proportion of aphids concentrating on variety A increased with the increasing proportion of that variety and with time. No differences in height were observed between variety A plants in the various plots, nor were there height differences between the different varieties within each plot.

## Borders and planting times

The third experiment tested two plot designs (each replicated three times) and two planting times, in mixtures of 60 plants of variety A with 20 plants of variety B: variety B planted as either two central or two border rows in the corresponding plots. In both cases, variety B was planted either simultaneously with variety A or 15 days before A. The mixtures were planted on May 21, 1986.

Plots in which variety A and two central rows of variety B were planted simultaneously accumulated the largest seasonal number of aphids per plot, with the aphids concentrating more on variety A than on variety B. Treatments 1, 3, and 4 did not differ in seasonal average number of aphids per plot (fig. 4). Significantly more aphids were found on variety A than on variety B in all treatments, except on treatment 3, where aphids concentrated significantly more on the border rows of variety B planted 15 days earlier than variety A.

In all except treatment 3, variety A, which accumulated more aphids than variety B, had lower biomass than variety B. In treatment 3, variety A, which was protected from aphids by variety B, had a higher yield than B (table 3).

## Conclusions

Mixing broccoli varieties in various space and time designs resulted in fewer cabbage aphids per plot and per plant than planting a single broccoli variety (Futura, Variety A). Aphid numbers decreased in plots as varietal diversity increased and as the proportion of variety A decreased. Planting of a preferred variety as a border row 15 days earlier than variety A gave significant protection to variety A from aphids.

Our observations seem to confirm that increased crop cultivar diversity in a field can result in fewer pests.

While it is difficult to explain the ways in which aphids responded to increased cultivar diversity, it is known that plant quality differences among closely related varieties can affect aphid population development. It is possible that differences in chemical or visual stimuli emanating from the varieties played a role. Data from the first and second experiments, however, suggest physical differences were important, since the dispersion of short varieties among tall plants restricted aphid settling on short plants. Taller varieties seemed to be more easily located by aphids, and functioned as a protective barrier or trap crop. This "physical interference" was apparent when the taller variety B was planted earlier as borders around variety A plants.

These results are encouraging and need to be studied further in larger plots more representative of farmers' fields.

**TABLE 1. Relation between plant height and number of cabbage aphids *(Brevicoryne brassicae)* in broccoli variety mixtures, Albany, California, spring 1985**

| Variety | Number of aphids/plant† | Average plant height* | $r^2$ |
|---|---|---|---|
| | | *cm* | |
| A | 632 ± 78.1 a | 36.8 ± 4.3 a | .941 |
| B | 595 ± 40.2 a | 34.0 ± 6.7 a | .958 |
| C | 410 ± 74.5 b | 27.8 ± 3.4 a | .884 |
| D | 416 ± 59.3 b | 30.6 ± 5.6 a | .785 |

† Cumulative number of aphids/plant present over a 50-day period.
* Means ± standard error followed by the same letter in the same vertical column are not significantly different, as determined by Duncan's multiple range test (P <.05).

**TABLE 2. Design of second experiment on variety proportions**

| Percent var. A per plot | Number of plants per plot of varieties: A | B | C | D |
|---|---|---|---|---|
| 100 | 80 | 0 | 0 | 0 |
| 75 | 60 | 7 | 7 | 7 |
| 50 | 40 | 13 | 13 | 13 |
| 25 | 20 | 20 | 20 | 20 |

NOTE: Each plot replicated three times.

**TABLE 3. Biomass production (at 60 days after planting) of varieties 'Futura' (A) and 'Orion' (B) at various combinations of planting times and arrangements**

| Treatment | Dry weight/plant: Var. A | Var. B |
|---|---|---|
| | *grams* | |
| B planted simultaneously with A as: | | |
| 1 (border rows)* | 984 ± 218 | 1,461 ± 162 |
| 2 (center rows) | 946 ± 210 | 983 ± 191 |
| B planted 15 days before A as: | | |
| 3 (border rows) | 1,375 ± 203 | 1,103 ± 159 |
| 4 (center rows)* | 1,191 ± 176 | 1,576 ± 171 |

* Within-treatment significant yield differences existed between varieties A and B, as determined by Duncan's multiple range test (P <.05). In treatments 2 and 3, differences were not significant.

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