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Compatibility of Intercropping with Mechanized Agriculture: Effects of Strip Intercropping of Pinto Beans and Sweet Corn on Insect Abundance in Colorado

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ABSTRACT The potential for management of insect pest densities by regulation of crop diversity through intercropping was examined in sweet corn and pinto beans. Insect abundance was monitored in corn and beans in alternating multiple-row patterns of 1, 2, 4, 8, and 16 rows. Insect responses to intercropping treatments were variable, with positive, negative, and neutral responses observed, depending on species of insect and crop. In some cases, insect abundance was affected by strip-intercropping widths of up to eight rows, suggesting that strip intercropping may be compatible with some types of mechanized agriculture.

INTERCROPPING, the simultaneous culture of two or more crops in the same field, is a common cultural practice in tropical countries (Andrews and Kassam 1976, Perrin and Phillips 1978). Intercropping takes various forms, from culture without a distinct row arrangement (mixed intercropping), to alternate single-row patterns (row intercropping) and alternate multiple-row patterns (strip intercropping). Crops may be grown at the same time, or may overlap slightly; in relay intercropping a second crop is planted after the first crop has reached its reproductive stage, but before harvest.

There are many benefits to be derived from intercropping, including reduction in insect pest abundance on crop plants. In a recent review of diversity in agroecosystems, Risch et al. (1983) reported that 53% of the herbivore species studied exhibited population decreases in diverse cropping patterns, while 18% were more abundant in diversified systems, and 9% were unaffected. Agricultural diversification through intercropping tends to be restricted to less developed countries, presumably because this cropping system is not economically feasible in mechanized, North American-style agriculture. However, such high-value, labor-intensive crops as vegetables and fruit may be appropriate systems for intercropping practices (Risch et al. 1983).

Despite a fairly significant effort to document the benefits of intercropping for various crop combinations (e.g., Altieri et al. 1978, Theunissen and Den Ouden 1980, Risch 1980, Risch and Hansen 1982) and crop-weed combinations (e.g., Altieri et al. 1977, 1981, Altieri and Gliessman 1983, Lathief and Ortiz 1983, Barney et al. 1984), and to

determine the ecological basis for this phenomenon (e.g., Root 1973, Bach 1980, 1981, Risch 1981) many questions remain unanswered. For example, what level of crop diversity (heterogeneity) is necessary for the benefits of intercropping to be obtained? We addressed this question by studying insect abundance in a corn/bean intercropping system with various row- and strip-cropped patterns. Our objective was to determine whether the insect-related benefits of intercropping could be derived from strip-cropped plantings on a scale that was compatible with mechanized agriculture.

Materials and Methods

A field study was conducted at Fort Collins, Colo., during 1983. Pinto beans ('Olathe') and sweet corn ('Jubilee') were selected as a model intercropping system since bean/corn is a traditional intercropping pattern in the tropics (Pinchinat et al. 1976). Also, their agronomic characteristics in Colorado (planting time, irrigation requirements, maturity, etc.) were compatible. Crops were planted 14 June. A randomized complete block design was used, with six treatments and eight replicates. Treatments consisted of alternate rows of corn and beans in ratios of 1 row beans:1 row corn (row intercropping), 2:2, 4:4, 8:8 (strip intercropping), and 16 rows of corn or beans. We considered these latter two treatments to be equivalent to monoculture. Plot size was 16 rows by 15.2 m; rows were 0.77 m apart. Stand density was 18 per m for beans and 6 per m for corn. The crops were not fertilized. Weeds were controlled chemically with alachlor (Lasso) at 3.4 kg/ha applied before planting and with appropriate postplanting mechanical tillage. During the season, the crops were furrow-irrigated four times. Soil type was Nunn clay loam with 2.1% organic matter and pH 7.7.

Insect populations were sampled in all plots at

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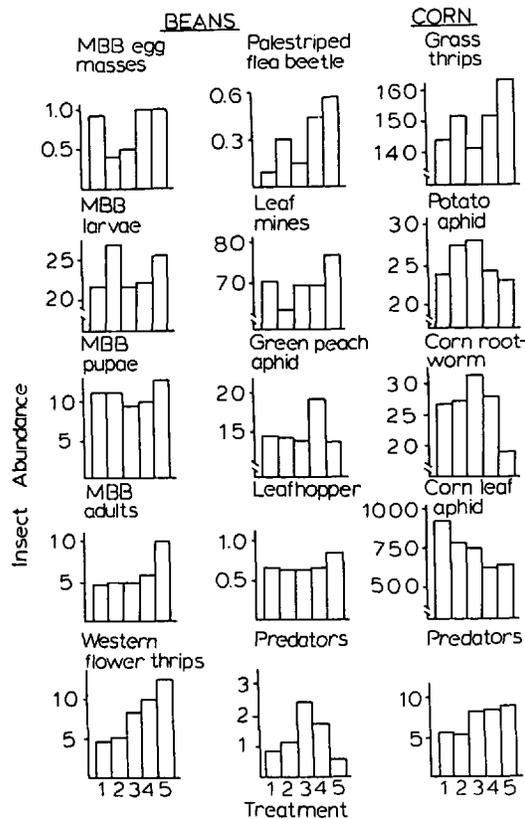


Fig. 1. Abundance of insects on beans and corn in an intercropping study, where treatment 1 is bean/corn strip width of 1 row: 1 row, treatment 2 is 2:2, treatment 3 is 4:4, treatment 4 is 8:8, and treatment 5 is 16 rows of bean or corn. Insect abundance is averaged over four sampling dates except for western flower thrips, where five samples were taken. Abundance is given as no. insects per 25 plants except for western flower thrips, where abundance is no. insects per 25 blossoms. MBB is Mexican bean beetle.

approximately 2-week intervals in mid- and late July and mid- and late August 1983. An additional sampling of beans was conducted 1 week after the mid-August sample (hereafter referred to as sample date 3b) because of the short life cycle of western flower thrips, *Frankliniella occidentalis* (Per-gande). Insects were sampled from 25 corn and bean plants per plot by visual examination in the four intercropping treatments and the two monoculture treatments. Plants were selected randomly in a transect pattern from plot corner to corner. None of the plants were damaged during the insect sampling procedures except where western flower thrips were sampled in beans. For this sample, a single new opened blossom per plant was torn apart and examined carefully for thrips.

Corn yield was assessed at maturity (20 Aug.) by randomly selecting 100 ears from each plot and examining them for insects and insect-related damage, and by determining wet weight. Insect-

related damage was rated visually on a scale (1-4) for silk and kernel damage, and for seed set, where a rating of 1 represented undamaged corn or complete seed set, respectively.

Bean yield was assessed by harvesting the center 3 m from each of eight rows per plot on 10 September. Pods, foliage, and debris were removed, and air-dried seed weight determined.

Data were analyzed by analysis of covariance and linear regression. Count values were transformed to square root for analysis. Significant means were separated with Duncan's (1955) new multiple range test at $\alpha = 0.05$. Leafhopper species could not be accurately separated in the field, so these data were pooled for analysis. Similarly, several predatory species occurred in low numbers, so they were grouped into a single category. Covariance was used because soil compaction affected plant growth in one row of plots on the edge of the experimental area. The analysis of covariance allowed partial adjustment for this extraneous variation. Data were analyzed separately for each date and crop.

Results and Discussion

A number of insects were significantly affected by intercropping. Patterns of insect abundance for some important species, averaged over sampling dates, are shown in Fig. 1.

In beans, the Mexican bean beetle, *Epilachna varivestris* Mulsant, was strongly influenced by bean/corn diversity, with adults generally demonstrating a preference for beans in more homogeneous, or 16-row, plots on both the first sampling date (overwintered beetles) and fourth sampling date (summer beetles) (Table 1). Larvae exhibited a similar distribution on the second sampling date. Leafhopper species apparently were slightly more abundant on beans in monoculture plots on the last date, although the low levels are probably of little biological significance. A positive response to plant homogeneity was shown by western flower thrips, although only the 16-row, monoculture plots had significantly more thrips on the second (3b) thrips sampling date.

In corn, adult western corn rootworms, *Diabrotica virgifera* LeConte, and corn leaf aphids, *Rhopalosiphum maidis* (Fitch), were significantly more abundant in the heterogeneous (narrow width) plots on the third sampling date. In contrast, palestriped flea beetles, *Systema blanda* Melsheimer, and *Phalacrus* sp., a shining flower beetle, were more abundant on homogeneous plots during the early sampling periods.

Several species did not respond significantly to intercropping patterns. Grass thrips, *Anaphothrips obscurus* (Müller), potato aphids, *Macrosiphum euphorbiae* (Thomas), greenbugs, *Schizaphis graminum* (Rondani), spider mites (two spotted spider mite, *Tetranychus urticae* Koch, and Banks grass mite, *Oligonychus pratensis* [Banks]) oc-

Table 1. Abundance of insect species (no. per 25 plants) that exhibited significant responses to intercropping^a

Crop	Date	Insect	Treatment				
			1	2	3	4	5
Corn	1	<i>Phalacrus</i> sp.	0a	0a	0a	0.25ab	0.37b
	2	Palestriped flea beetle	0a	0a	0a	0a	0.25b
	3	Western corn rootworm	4.92b	4.34b	5.65b	4.11ab	1.96a
	4	Corn leaf aphid	3,502b	2,864ab	2,772ab	2,279a	2,365a
Bean	1	Mexican bean beetle adults	1.00ab	1.12ab	0.25b	1.12ab	2.00a
	2	Mexican bean beetle larvae	12.23ab	8.37b	14.62ab	16.87ab	18.87a
	3a	None					
	3b	Western flower thrips	15.25a	15.87a	21.75a	24.12a	36.62b
	4	Mexican bean beetle adults Leafhopper spp.	16.50a 0a	16.37a 0a	17.87ab 0a	20.00ab 0a	35.87b 0.25b

Means within rows followed by the same letter are not significantly different ($P < 0.05$; Duncan's [1955] new multiple range test).

^a Data from species that did not demonstrate statistically significant differences are not presented. See text for dates, and Fig. 1 legend for treatments.

curred on corn foliage. Green peach aphids, *Myzus persicae* (Sulzer), bean aphids, *Aphis fabae* Scopoli, pea aphids, *Acyrtosiphum pisum* (Harris), and vegetable leafminers, *Liriomyza sativae* Blanchard, occurred on beans. Predators commonly occurring on both corn and bean foliage included common green lacewings, *Chrysopa carnea* Stephens, convergent lady beetles, *Hippodamia convergens* Guerin-Meneville, and minute pirate bugs, *Orius tristicolor* (White). When corn ears were sampled at maturity, larvae of European corn borers, *Ostrinia nubilalis* (Hübner), corn earworms, *Heliothis zea* (Boddie), and western bean cutworms, *Loxagrotis albicosta* (Smith), were found at low levels of abundance, with only 0.05, 1.64, and 1.41% of the corn ears infested, respectively.

Intercropping patterns had pronounced effects on corn and bean yield, with bean yield positively correlated, and corn yield negatively correlated, with crop homogeneity (Fig. 2). This pattern commonly results when crops of dissimilar height compete for light (Trenbath 1976). Optimal crop ratios can be calculated using the "relative yield total" technique (Trenbath 1976), but the crop varieties selected for this study were not adapted for intercropping, which precludes realistic assessment. Insect damage to corn ears did not differ significantly among treatments.

The observed insect responses are consistent with those of previous studies. Some species (e.g., Mexican bean beetle, western flower thrips) were favored by, or attracted to, homogeneous plots, while several species were unaffected by intercropping, and two species (western corn rootworm and corn leaf aphid) apparently were favored by heterogeneity. Thus, abundance of important crop pests

was decreased in beans, but increased in corn, by bean/corn intercropping. The significance of the studies, however, is related not to whether positive or negative effects occurred, but where they occurred on the continuum of crop heterogeneity/homogeneity.

The abundance of corn- and bean-feeding insects was shown to be amenable to manipulation by strip intercropping, and in several cases the insect densities did not differ significantly among one-, two-, four-, and eight-row "strips," but were significantly different from 16-row "monocultures." Therefore, the benefits of tropical inter-

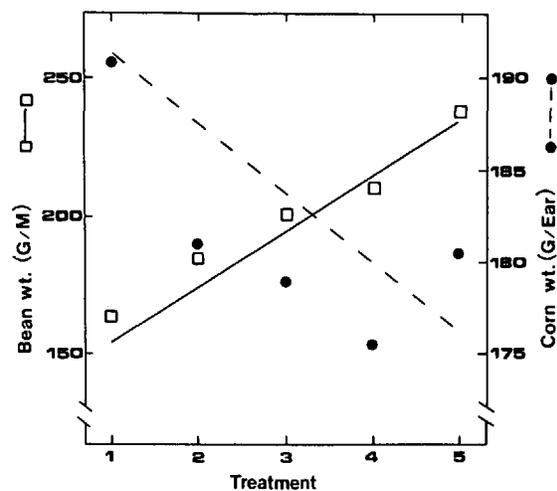


Fig. 2. Yield of dry beans (g/row-m) and sweet corn (g wet wt per ear) from intercropping plots; see Fig. 1 legend for treatment descriptions. Regression equation for beans is $Y = 147.37 + 17.03X$ ($r = 0.987$); equation for corn is $Y = 190.40 - 2.80X$ ($r = -0.732$).

cropping systems related to insect management also may be obtained in mechanized cropping systems where multiple-row planting and harvesting is practical. Other intercropping systems using crop varieties adapted for competition, or crops with more uniform height, may be more practical than the model system studied herein. As suggested by Risch et al. (1983), intercropping may be more appropriate for vegetable and fruit crops than for field crops. However, where benefits other than pest management can be derived from intercropping (e.g., wind protection [Radke and Hagstrom 1976]), even field crops or crops with different heights should be considered as candidate systems.

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