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A REVIEW OF INSECT PREVALENCE IN MAIZE (*ZEA MAYS* L.) AND BEAN (*PHASEOLUS VULGARIS* L.) POLYCULTURAL SYSTEMS

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ABSTRACT

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Tropical agroecosystems often include two or more crops arranged in diverse polycultural patterns. Experimental evaluation of the pest situation in polycultural systems was carried out in several field experiments at CIAT (Centro Internacional de Agricultura Tropical, Palmira, Colombia) with maize and beans in monoculture and polyculture.

Beans grown as maize/bean polycultures had 26% fewer *Empoasca kraemeri* Ross and Moore adults than monoculture beans. Similarly the populations of *Diabrotica balteata* Le Comte were 45% less in polycultures. *Spodoptera frugiperda* (Smith) incidence as cutworm in maize was reduced 14% in polycultures. Also these systems had 23% less infestation of fall armyworm as whorl feeder.

Date of planting affects pest interactions in these systems. For example, maize planted 30 and 20 days earlier than beans reduced leafhoppers on beans by 66% as compared to simultaneous planting. Fall armyworm damage on maize was reduced 88% when beans were planted 20 to 40 days earlier than the maize.

Diversification of monocultural systems with other crops, especially non-host plants, seems to be one effective strategy in tropical pest management. Further research will provide a basis for incorporating practical pest control schemes into the most important intercropping systems in the tropics.

INTRODUCTION

Agricultural systems are designed to alter a given ecosystem to increase the flow of energy to man. Within this scope crop monocultures are extreme examples of environmental simplification and specialized management. Although highly productive and efficient, these systems have been criticized because of their genetic and horticultural uniformity, and the resulting continuous pest susceptibility (Pimentel, 1961; Southwood and Way, 1970; Nickel, 1973; Van Emden and Williams, 1974).

Current approaches to pest management involve the integration of several methods of control, and depend on several characteristics of agroecosystems. One of the most important is the diversity of vegetation within the crop area (MacArthur, 1955; Elton, 1958; DeLoach, 1970). There is greater stability of animal populations in complex ecosystems than in simple ones. In agriculture, this has been demonstrated in collard weed diversified agroecosystems (Pimentel, 1961; Tahvanainen and Root, 1972; Smith, 1976). Based on these theoretical concepts and on some preliminary experimental data, it may be concluded that some multiple cropping systems (mixed or intercropped) are less vulnerable to insect population outbreaks, than monoculture systems.

This paper discusses the most relevant ecological characteristics of these systems and how they affect insect diversity and stability. Following a literature review, experimental results are presented from maize/bean polycultures and corresponding monocultures in the Colombian tropics.

STRUCTURE AND FUNCTION OF POLYCULTURAL SYSTEMS

The terms polyculture, mixed cropping, double cropping, crop associations, intercropping and others have been used interchangeably to describe the planting of more than one crop in the same area in one year.[1] These systems can more efficiently fill a microclimatic niche, and more efficiently use each unit of land area (Igzoburike, 1971).

Polycultures are defined by Hart (1974) as systems in which two or more crops are simultaneously planted within sufficient spatial proximity to result in interspecific competition and complementation. These interactions may have inhibitory or stimulating effects on yields, and depending on these effects polycultures can be classified as amensalistic, comensalistic, monopolistic and inhibitory (Hart, 1974). In the design and management of these systems, one strategy is to minimize negative competition and maximize positive complementation among species in the mixture (Francis et al., 1976).

In the tropics, polycultures have been an important component of small-farm agriculture, and one of the reasons for the evolution of these cropping patterns may be less incidence of insect pests (Francis et al., 1976, 1977a). According to Holdridge (1959) and Dickinson (1972), the most rational agricultural system for the tropics is that which most closely simulates the energy flow and structural characteristics of diverse natural tropical ecosystems. They conclude that monocultures are ecologically unsound and are not sustainable for the long-term social and economic well-being of small farmers.

A modification of the comparison of monocultures and polycultures by Dickinson (1972) is shown in Table I. The more obvious agronomic differences in production, resource utilization and stability contribute to more subtle interpretations of the social and economic consequences of these systems for the small farmer. It should be stressed that current food production

[1] An attempt to standardize this terminology was published by ASA (Special Publication No. 27, 1975). In our review the term polyculture will be used.

in tropical countries depends heavily on both types of systems, one an essentially "monoculture sector" typical of large commercial farms, and the other a more marginal small-farm "polyculture sector".

PEST SITUATION IN POLYCULTURAL SYSTEMS

Litsinger and Moody (1975) described the status of integrated pest management in multiple cropping systems, including some examples of the behavior of insect pests in mixed and strip cropping systems. They ascribe the regulation of insect pests in polycultures to physical interference (protection from wind, hiding, shading, alteration of color or shape of the stand) and to biological interference (production of adverse chemical stimuli, presence of predators and parasites).

One important biological feature of multiple cropping is its increase in diversity of both the flora and the fauna (Raros, 1973). One hypothesis frequently used to explain smaller herbivore populations in complex environments (i.e. polycultures) is that predators and parasites are more effective in this situation (Root, 1973). In experimental conditions diversity and activity of natural enemies have been higher in monocultures than in polycultures, mainly due to migration of agents from diversified plots, and a marked concentration of preys and hosts in monocultures (Pimentel, 1961; Root, 1973). These contradicting results suggest that factors other than natural enemies are responsible for much of the observed differences between simple and diverse habitats.

In discussing the influence of vegetational diversity on phytophagous populations, Tahvanainen and Root (1972) state that interplanting non-host plants can drastically decrease colonization efficiency and subsequent population density. In these systems the chemical stimuli that induce landing seem to become "lost" in the environment. In addition to their taxonomic diversity, diversified systems have a relatively complex physiognomy and associated pattern of microclimates; thus insects may experience further difficulty in locating spots of favorable microclimatic conditions.

The biotic, structural, chemical and microclimatic complexity of these polyculture habitats results in an associational resistance of the community that ameliorates the herbivore pressure. Crop species growing in monocultures lose most of this associational resistance.

Specific examples of polycultures in which associational resistances have been demonstrated experimentally are listed in Table II. In each case, the main factor involved in the regulation of the pest population is also mentioned.

It is critical to select the correct plant diversity for a given microclimatic/ biotic situation; a specific diversity in the same system can be beneficial in one place but harmful in another. For example, in Tanzania and California intercropping corn and cotton increases *Heliothis virescens* damage, but in Peru (Cañete Valley) this system favored the control of *Heliothis* (Southwood

TABLE I

Comparison of several characteristics of monocultures and polycultures (modified from Dickinson, 1972)

Characteristics	Monoculture	Polyculture	Example	Factor involved	References
Net production	High (specially if given fossil fuel subsidy)	30% higher than monocultures when achieving correct planting dates, plant density and crop varieties	Maize/bean associations in tropical Colombia	Not reported	Francis et al., 1976
Biochemical contribution to diet	Low	High, complete	Maize/bean associations in Central America. Farmers commonly consume about 500 g of maize and 100 g of black beans per day, which provides about 2118 cal and 68 g of protein daily	Corn and beans complement each other in essential amino acid patterns	Pimentel et al., 1975
Species diversity	Low — generally devoted to a single variety of the same age	High	Natural succession analog cropping systems of Central America with a dominant stratum composed by coconut, mango and avocado	Not reported	Holdridge, 1959
Light and soil resources	Poor — frequently with bare soil unoccupied by photosynthetic material	High	Polycultural systems in Philippines show a high pattern of light interception and a high efficiency in the use of applied nitrogen	Increased leaf area index and radical space	IRRI, 1973

Inherent stability					
a. Weed performance	Poor in general: often needs chemical herbicides or continuous hoeings	Good competitive ability	Maize + mungbean associations give excellent competitive control in Philippines	Light interception	Bantilan and Harwood, 1973
b. Pest status	Violent fluctuations	Stable	All reported in Table II	Biotic, microclimatic and chemical factors	Table II
Nutrient cycles	Open — large proportion of all nutrients applied to crops is lost seasonally to leaching	Tight — minerals lost by early successional annuals taken up by perennial crop plants; erosion control	Natural succession analog cropping systems in tropical America	Nutrient recycling: nutrient robbing propensity of some crops is counteracted by the enriching quality of organic matter to the soil; continuous rather than seasonal	Igzoburike, 1971; Dickinson, 1972
Economic stability	"Boom or bust" — with optimal environmental and market conditions, large fossil fuel investments, high yields and profits possible; vulnerable to environmental stress, market fluctuations beyond farmer's control; labor requirements highly seasonal; tendency for mechanization to replace human labor	High — variety of food produced for region or national consumption assures market for some crops; flexibility to switch plant energy flow from direct marketing to increased animal production; low capital investment makes subsistence on a quality diet feasible; yield and labor input programmed throughout year	Natural succession analog cropping systems in tropical America	——	Igzoburike, 1971; Dickinson, 1972

(continued)

TABLE I (*continued*)

Characteristics	Monoculture	Polyculture	Example	Factor involved	References
Social viability	Volatile — economics of scale concentrate management decisions, production and profit in control of national socio-economic elite or foreigners; foreign control of markets common, dependence on fossil fuel inputs creates need for satellite relationship with developed countries	Initially volatile, but contributes to long-term stability; emphasis on direct involvement of peasant farmers in ecological and economically viable systems of quality food production; functional systems a valuable resource in serious agrarian reform; low ratio of land-owning managers to agricultural laborers	Natural succession analog cropping systems in tropical America	—	Igzoburike, 1971; Dickinson, 1972

and Way, 1970). Also specific diversities can regulate one pest population, while it stimulates others. Further research is needed in this area.

STUDIES CONDUCTED IN TROPICAL COLOMBIAN AGROECOSYSTEMS

In the Colombian tropics, Francis et al. (1977a, b) have been investigating agronomic aspects of maize/bean polycultures such as: relative planting dates, plant densities, planting systems and varieties. Little is known about the dynamics of maize and bean pests in these systems. The behavior of insect populations in this association was studied in several field experiments at the Centro Internacional de Agriculture Tropical (CIAT) in the Cauca Valley of Colombia.

In CIAT the most common bean pests are *Empoasca kraemeri* Ross and Moore (Homoptera: Cicadellidae) and chrysomelids, of which *Diabrotica balteata* Le Comte is the principal species. The main corn pest is *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae), which attacks both the emerging seedling and later the whorl.

Simultaneous planting of maize and beans

A maize/bean polyculture with simultaneous planting date for both crops was compared to monocultures of the same varieties. Plots of 80 m^2 replicated three times in a randomized complete block design were planted with the black bean variety ICA Pijao at 160 000 plants per hectare, the yellow ICA H-207 maize double cross hybrid at 40 000 plants per hectare, and polyculture combining these two crops with the same plant densities as in monocultures. Plots were fertilized with 300 kg/ha NPK (15-15-15), and kept weed-free with pre-emergence application of 1.92 kg/ha of H-22234 and 2.8 kg/ha of DNBP.

Bean insect populations were sampled each 10 days on 80 bean plants with a D'Vac vacuum insect net (Model 1, 3 HP). *E. kraemeri* nymphal populations were sampled 20, 60 and 70 days after planting by counting number of nymphs per 15 bean leaves in each plot. Cutworm damage on maize was evaluated by counting the total number of seedlings destroyed at 10 and 15 days after planting. Damage to the whorl was quantified by counting the larvae population on 40 maize plants at 20, 40, 50 and 60 days after planting.

Results of this planting system showed significantly fewer adult leafhoppers on beans in the maize/bean polyculture compared to monoculture beans, on the final sampling date 70 days after planting (Fig. 1). Nymphal populations were not affected by diversity in cropping systems. *Anagrus* sp. (Hymenoptera: Myrmaridae), the main egg parasitoid of *E. kraemeri*, showed 20% higher activity in polycultures with 48.5% parasitism in monoculture vs. 60.7% parasitism in association. The occurrence of natural predators was significantly higher in polyculture at 40 days from planting (Figs. 2 and 3). Principal predators were *Condylostylus* sp. (Diptera: Dolichopodidae) and some Hemiptera (Reduviidae and Nabidae). These insects show higher densities in polycultures

TABLE II

Pest situation in polycultural systems

Polycultural system	Pest regulated	Factor involved	Reference
Cotton intercropped with forage cowpea	*Anthonomus grandis*	Population increase of parasitoids (*Eurytoma* sp.)	Marcovitch, 1935
Peaches intercropped with strawberries	*Ancylis comptana* *Grapholita molesta*	Population increase of parasitoids (*Macrocentrus ancylivora*, *Microbracon gelechise* and *Lixophaga variabilis*)	Marcovitch, 1935
Strip cropping of cotton and alfalfa	*Lygus hesperus* and *L. elisus*	Prevention of emigration and synchrony in the relation between pests and natural enemies	Van den Bosch and Stern, 1969
Strip cropping of cotton and alfalfa on one side and maize and soybean on the other	*Heliothis zea* and *Trihoplusia ni*	Increased abundance of predators (*Orius insidiosus*, *Hippodamia convergens* and *Coleomegilla maculata*)	DeLoach, 1970
Intercropping cotton and sorghum or maize	*Heliothis zea*	Increased abundance of predators (*Hippodamia* sp., *Nabis* sp., *Chrysopa* sp. and *Collops* sp.) due to the presence of alternative preys (*Rhopalosiphum maidis* and *Schizaphis graminum*)	Fye, 1972; Burleigh, 1973
Maize intercropped with canavalia	*Prorachia daria* and *Spodoptera frugiperda*	Not reported	Guevara, 1972
Tomato and tobacco intercropped with cabbage	*Phyllotreta cruciferae*	Feeding inhibition by odors from non-host plants	Tahvanainen and Root, 1972
Tomato intercropped with cabbage	*Plutella xylostella*	Chemical repellency or masking	Raros, 1973
Peanut intercropped with maize	*Ostrinia furnacalis*	Abundance of predatory spiders (*Lycosa* sp.)	Raros, 1973

Intercropping cabbage with white and red clover	*Erioischia brassicae*, *Brevicoryne brassicae* and *Pieris rapae*	Decreased colonization and reproduction and abundance of predators (*Harpalus rufipes* and *Phalangium apilio*)	Dempster and Coaker, 1974
Intercropping cowpea and sorghum	*Ootheca* sp.	Interference of air currents	Litsinger and Moody, 1975
Sesame intercropped with sorghum	*Antigostra* sp.	Shading by the taller companion crop	Litsinger and Moody, 1975
Maize and bean polycultures polycultures	*Empoasca kraemeri* and *Diabrotica balteata* on beans, and *Spodoptera frugiperda* on maize	Herein reported	——

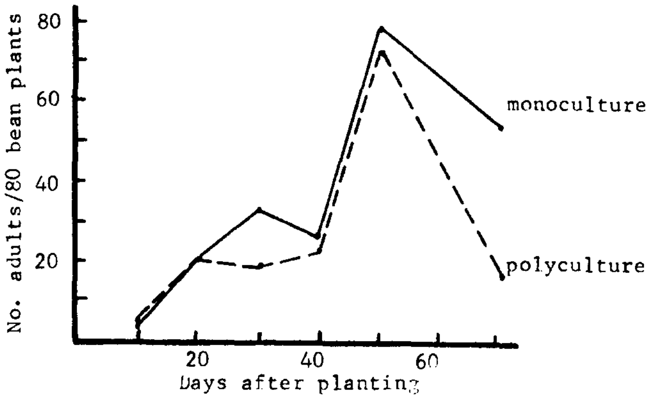

Fig. 1. *E. kraemeri* adult population dynamics in bean mono- and polycultures (with maize).

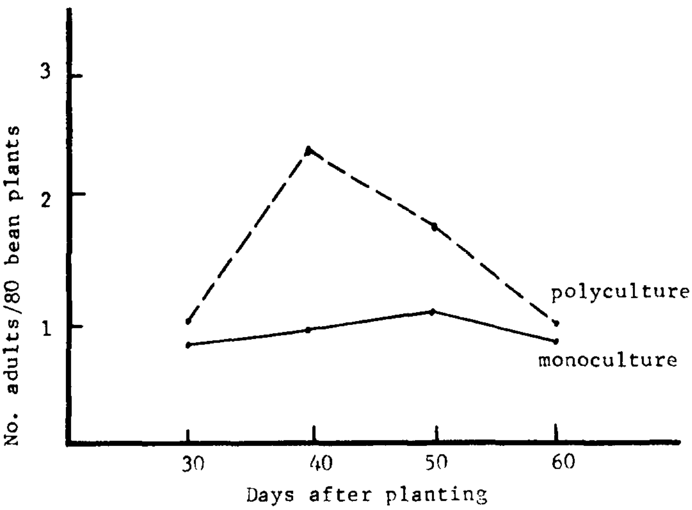

Fig. 2. Predator *Condylostylus* sp. abundance in bean mono- and polycultures (with maize).

than in monocultures, but 50 days after planting they show an opposite behavior suggesting a migratory trend toward monocultures (Fig. 3). A preliminary microclimatic monitoring was performed in both systems utilizing a common hygrometer, a YSI thermometer and a Weston Model 756 radiometer. There were no differences in temperature and relative humidity between mono- and polycultures, although light interception at the middle of the bean canopy was 19.3% higher in polycultures. Saxena and Saxena (1974) demonstrated that light is a vital factor that conditions food ingestion in leafhoppers. Shading conditions in polycultures may be another factor contributing to the reduction of *E. kraemeri* populations.

Diabrotica balteata, a polyphagous insect, showed 45% less adult population in polycultures (Fig. 4). The increased population of their reduviid

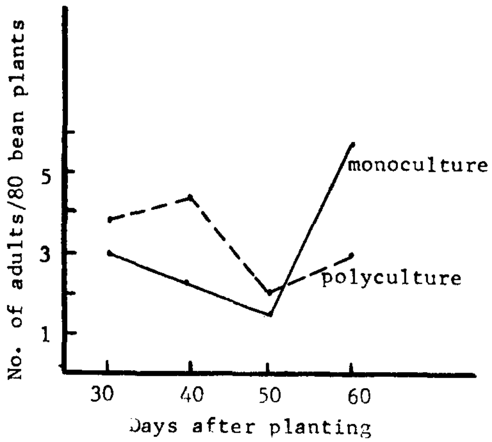

Fig. 3. Predator Hemiptera abundance in bean mono- and polycultures (with maize).

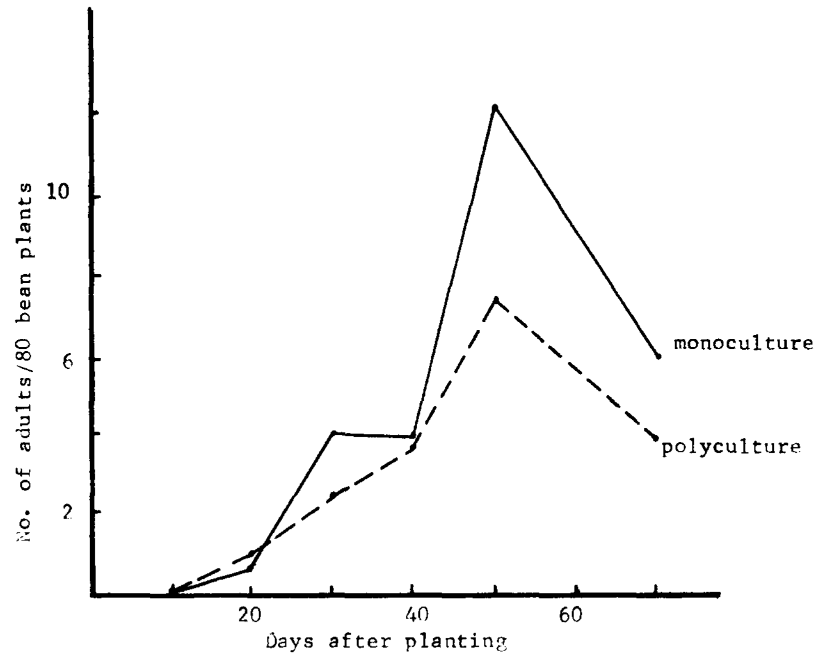

Fig. 4. *D. balteata* adult population dynamics in bean mono- and polycultures (with maize).

predators in polycultures probably was an important regulatory factor. It is possible that the presence of other chrysomelids which was 30% higher in polyculture, exerted a competitive displacement of *D. balteata*, decreasing its feeding and colonization efficiency. The number of bean plants with physical damage to leaves was similar in poly- and monocultures.

Cutworm damage to maize by *Spodoptera frugiperda* was 14% lower in polyculture than in maize monoculture (non-significant). The number of fall armyworm larvae on corn plants was significantly higher in monocultures than in polycultures. *Meteorus* sp. (Hymenoptera: Braconidae), a common parasitoid of *S. frugiperda* larvae, showed similar activity in both habitats (average 24.5%), thus suggesting the existence of other factors (odors, shading, etc.) which exert a regulatory pressure on *Spodoptera* in polycultures.

Comparisons of fall armyworm attack in three agronomic trials are summarized in Table III. In association with bush bean (var. ICA-Pijao) planted one week before the maize, there was significantly lower insect attack in all cases. In association with the climbing bean (var. P-259), this difference was present in two of the comparisons. Bush bean varieties seem to exert a stronger regulatory effect than climbing bean varieties. These data confirm the previous qualitative observations of reduced infestation in polycultures, and represent a potential for cost savings to the farmer who preserves some diversity in his cropping system.

Sequential planting of maize with respect to beans

A maize/bean polyculture with sequential planting of maize and a single date for beans was designed to determine the effects of these treatments on insect pests in beans. Plots of 64 m^2 replicated three times in a randomized complete block design were planted with the same black bush bean (var. ICA-

TABLE III

Spodoptera frugiperda (fall armyworm) incidence on 40 maize plants in two planting systems in three trials (Francis et al., 1977b)*

Trial number	Maize hybrid	Bean variety	Maize system	Maize grain yield (kg/ha)	Fall armyworm attack		
					Date 1 (15 days)	Date 2 (27 days)	Date 3 (43 days)
7501	H-207	P-259	Mono.	6535	46.4	27.6	29.4
			Poly.	7318	28.2	25.0	21.6
7501	H-210	P-259	Mono.	8205	37.2	25.0	21.4
			Poly.	8153	44.0	14.2	17.8
7501	H-207	Pijao	Mono.	6535	46.4	27.6	29.4
			Poly.	7631	7.8	4.4	9.0
7501	H-210	Pijao	Mono.	8205	37.2	25.0	21.4
			Poly.	8769	4.2	3.4	7.6
7502	H-207	Pijao	Mono.	7221	56.0		
			Poly.	6926	24.7		
7515	H-207	P-259	Mono.	5600	13.0		
			Poly.	4177	4.0		

*Comparisons between monoculture and associated culture do not differ significantly ($P < 0.05$) when two data are joined by a vertical line.

Pijao) and yellow hybrid maize (H-207). Planting dates of maize were 40, 30, 20 and 10 days before beans, simultaneous planting, and 10 and 20 days after beans; these were designated +40, +30, +20, +10, 0, −10 and −20, respectively. *Empoasca kraemeri* and *Diabrotica balteata* adult populations were sampled 10, 20, 50 and 60 days after planting on 80 bean plants per plot. *E. kraemeri* nymphs were sampled on 30 bean leaves 30 and 40 days after planting. The trial was repeated in a second season, eliminating the 40-days treatment.

The effect of planting date of maize on adult *E. kraemeri* is summarized in Table IV, showing significantly reduced levels of infestation when maize was planted 20 to 40 days before the beans. Results from the second season confirmed that adult leafhopper populations are significantly reduced in beans

TABLE IV

Effect of different maize planting dates relative to beans on the adult population of *E. kraemeri* on 80 bean plants in two seasons (average of three replicates)

First season

Maize planted	Sampling dates (days after planting)				
	10	20	50	60	Average
	Number of adults/80 bean plants				
40 days before	41.0	19.0	19.0	21.0	25.0b*
30 days before	13.0	12.0	24.0	39.0	22.0b
20 days before	48.0	23.0	10.0	18.0	24.7b
10 days before	78.3	27.0	22.3	32.6	40.1a
Simultaneously	46.3	30.7	36.0	39.3	38.1a
10 days after	47.0	34.3	34.3	28.0	35.4a
20 days after	16.0	63.0	32.0	50.0	40.2a

Second season

Maize planted	Sampling dates (days after planting)					
	10	20	30	40	50	Average
	Number of adults/80 bean plants					
30 days before	1.6	4.3	14.6	47.3	60.6	25.7c*
20 days before	9.6	20.6	41.0	132.6	159.6	72.3b
10 days before	42.0	42.3	42.0	337.3	227.6	138.2ab
Simultaneously	40.6	40.3	48.0	322.0	208.3	133.1ab
10 days after	38.0	37.6	70.0	396.6	220.3	152.4a
20 days after	34.3	56.3	55.3	326.6	270.0	144.5ab

*Numbers followed by the same letter in each column do not differ significantly (5% level).

when maize is planted first (Table IV, lower half). Nymphal populations of leafhopper were lowest in the treatments with maize planted 10 to 40 days before the beans. This confirms previous results (CIAT, 1974) in which lowest nymphal populations occurred when maize was planted 20 days before the beans. *Diabrotica balteata* adult populations were reduced only by the 30-day advanced planting of maize (Table V).

Sequential planting of beans with respect to maize

A maize/bean polyculture with sequential planting of beans was designed to determine the effect of relative planting date on fall armyworm population on maize. In the first trial, the plot design and size were identical to the trial with sequential maize plantings. Insect populations were evaluated by larval counts taken 20, 27, 35 and 43 days after planting. Average data over these dates are shown in Table VI. Action of *Spodoptera* as cutworm was not encountered in this trial. Significantly lower levels of infestation in maize were observed with beans planted 20 to 30 days before, with higher and uniform populations from treatments with beans planted 10 days before to 20 days after the maize. Populations in maize were reduced by 88% by the early plantings of beans. Maize yields did not vary significantly among these bean-planting dates.

A second trial employed the same design with two bean varieties in association with maize: ICA Pijao (bush) and P-589 (climber). Fall armyworm larval population was evaluated 10, 20 and 30 days after planting, with no differences among these dates. Cutworm attack did not occur in this trial either. Again, a slightly lower level of damage as whorl worm was observed on maize associated with bush beans, compared to maize associated with climbing beans (Table VI). Beans planted 20 to 30 days before maize substantially reduced

TABLE V

The effect of different planting dates of maize relative to beans on the adult population of *D. balteata* on 80 bean plants on five different dates (average of three replicates)

Maize planted	Sampling dates (days after planting)					
	10	20	30	40	50	$\bar{x}$
	Number of adults/80 bean plants					
30 days before	0	1.0	0	3.0	17.0	2.4b
20 days before	0	1.0	7.6	12.3	26.6	9.5a
10 days before	0	3.3	16.3	22.3	16.0	11.6a
Simultaneously	0.3	3.0	7.6	14.6	12.3	7.6a
10 days after	0.6	8.6	20.6	22.0	17.3	13.0a
20 days after	1.0	1.0	8.3	27.0	20.3	11.5a

TABLE VI

Effect of different planting dates of two bean varieties on the population of *Spodoptera frugiperda* on 40 maize plants (average of four sampling dates and three replicates of two trials)

Beans planted	First trial	Second trial	
	Maize/bush beans	Maize/bush beans	Maize/climbing beans
	Number of larvae/40 maize plants		
30 days before	1.63a*	0	0
20 days before	7.80a	6.7a	10.2a
10 days before	22.30b	18.6b	22.6b
Simultaneously	25.80b	20.9b	15.8c
10 days after	27.70b	27.4b	20.4b
20 days after	29.40b	10.7c	16.3c

*Numbers followed by the same letter in each column do not differ significantly (5% level)

the fall armyworm attack in maize. Although there was no attack in the +30 treatment, this maize suffered from competition from the associated bean crop at its initial stages.

CONCLUSIONS

Maize/bean polycultures are among the important traditional tropical agricultural ecosystems. This review and our results indicate that these systems are characterized by reduced pest populations compared to monocultures of the same crops, suggesting that this may be one reason for the existence of these polycultures in the tropics. Although the regulation mechanisms are not fully understood, some factors which condition a lower pest incidence in polycultures than in monocultures are more natural enemies, microclimatic gradients (mainly shading) and chemical interaction. These factors function together as an associational resistance. In the case of *Empoasca kraemeri*, *Diabrotica balteata* and *Spodoptera frugiperda* all these factors may interact. It is possible that changes in color, texture and shape of the crop canopy in polycultural stands may vary the optical stimuli available to these insects and decrease their colonization efficiency. There may also be some adverse chemical stimuli which come from the respective companion plants.

It is recommended that this research continue and the results on polycultures be incorporated into modern pest management systems. In addition to selecting the most appropriate crop diversity, researchers should explore strategies for pest control in conjunction with agronomic research to maintain acceptable yields. It is critical to develop new and high yielding cropping patterns without creating conditions that favor new and equally high potentials for pest damage. Many monoculture systems promote these pest problems. The adoption of multiple cropping is not appropriate to all zones nor all scales of farming due to high labor requirements and reduced production of particular crops. These systems are especially important to the small farmer in the tropics of the world, and some research must be directed toward improving these systems with elements of the available new technology.

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