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Effects of Mixed Cropping on a Soil Nematode Community in Honduras[1]

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Abstract: Nematode-resistant tropical legumes are effective in reducing populations of plant-parasitic nematodes when used in rotation systems. Mixed cropping is a common practice of many small farmers in Central America, but little is known about the effects of tropical legumes on nematode communities under these systems. To examine the effects of intercropping on the nematode fauna associated with squash (*Cucurbita pepo*) and cucumber (*Cucumis sativa*) in Honduras, two field experiments were conducted to compare nematode density and diversity in soil under cucurbits grown as a monocrop with that in soil under cucurbits intercropped with alfalfa (*Medicago sativa*) or hairy indigo (*Indigofera hirsuta*). A parallel series of field tests compared soil nematode communities associated with a cucurbit monocrop and a cucurbit intercropped with marigold (*Tagetes patula*), which may decrease nematode populations through the production of toxic root exudates. Among all four tests, over a period of 90 days, there were no consistent differences in densities of various nematode genera or trophic groups in intercropped versus monocropped plants, nor were there consistent differences in community diversities among treatments.
Key words: agroecology, cropping system, ecology, intercropping, mixed cropping, nematode, nematode community.

Rotation of susceptible plants with nematode-resistant plants has long been recommended as an appropriate strategy for management of plant-parasitic nematodes (16). Although it is difficult to find rotation crops to manage root-knot nematodes (*Meloidogyne* spp.), which have a very wide host range, several plants have been identified as potentially favorable for reducing populations. Hairy indigo and marigold have both been found to decrease soil populations of *Meloidogyne incognita* (15), which is one of the most severe pests on cucurbits in southern Honduras. Alfalfa Florida 77, was recommended by Baltensperger et al. (3) for use in tropical crop rotation systems because it was found to be resistant to root-knot nematodes and to have good persistence in tropical climates.

Crop rotation is generally practiced by large-scale producers in Honduras, but small farmers are more likely to adopt mixed cropping systems in order to diversify and increase production on a land-unit basis while also minimizing the risk of total crop failure. Because most small-scale farmers must rely on ecological means of pest management, nematode-resistant plants would be a beneficial introduction to their systems. Alfalfa and hairy indigo, which are both high quality, nutrient-rich cattle feeds (2,7), would be particularly useful if animal production systems were integrated with the plant systems. Marigold, though not used for cattle production, is often used as a chicken feed in Central America to improve yolk color in eggs.

The majority of studies of nematodes in agroecosystems have focused on plant parasites, due to their economic impact on crop plants. Fewer studies have examined the decomposition-based nematode community. In addition, research on the effects of mixed cropping systems on soil nematode communities has been largely limited to work done in Asia and Africa (1,5,8). In 1988, Noe reviewed tropical agricultural systems research and concluded that basic data on nematode communities under mixed cropping systems are still relatively scarce (10).

Of primary importance to any grower considering the adoption of a farming sys-

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tem is the economic viability of the system, since these growers must often support large families on relatively small plots. The objectives of this study, then, were to investigate the potential influence of four intercropping systems on the nematode community of an agricultural soil and to determine the yield and economic feasibility of each system.

Materials and Methods

Field experiments were conducted in two adjacent fields at the Panamerican School of Agriculture in the Yeguare Valley of Honduras in 1991. Both fields had been in horticultural production for several years prior to this investigation. Beet, okra, and alfalfa were the three most recent plantings. The soil type was loam (35% sand, 42% silt, 23% clay). Four intercropping systems were studied: squash–legume, squash–marigold, cucumber–legume, and cucumber–marigold.

In all systems, the design was a randomized complete block with five replications of each treatment. Individual plots within the legume systems were 12 m long and 5.5 m wide, with five beds per plot. Treatments consisted of a cucurbit grown as a monocrop control or intercropped with hairy indigo (*Indigofera hirsuta* L.) or alfalfa (*Medicago sativa* L.). Individual plots within the marigold systems were 5 m long and 3.3 m wide, with three beds per plot. Treatments consisted of a cucurbit grown as a monocrop or in association with marigold (*Tagetes patula* L.). The legume and marigold experiments were conducted simultaneously. Both experiments were repeated, with the same plots replanted during the second season. Cucurbits were chosen according to local preference, based on the season. The cucurbits used were yellow squash (*Cucurbita pepo* L.) in early 1991 and cucumber (*Cucumis sativa* L.) in late 1991.

Beds were 0.8-m wide, and a distance of 0.3 m was left between each bed. Within all cropping systems, the associated crops were planted along the borders of the bed in two rows. Legumes were seeded with a manual push planter, at a density of approximately 100 seeds/meter. At the same time, marigold was seeded in trays in a greenhouse, then transplanted to the field 2 weeks after seeding (at a spacing of 0.5 m), during which time the legumes were allowed to become established in the field. The plots for monocropped squash were left fallow during this period.

The cucurbit was seeded in the greenhouse 5 days after the associated crops were planted. Nine days after seeding, they were transplanted to the center of each bed in all field plots. Yellow squash, used in the early experiments, was spaced at 0.5 meters. Cucumber, used in the later experiments, was spaced at 0.25 meters, then staked after 2 weeks. No fertilizer was applied, and irrigation was by furrow irrigation. Safer's Insecticidal Soap and parathion were used to manage aphids, whiteflies, and melonworm (*Diabrotica* spp.). Weed control was done by hand in all plots. Cucurbit harvests were taken from 10 plants in the middle rows of each plot every 2 days over a 2–3 week period, and was measured as both total number and fresh weight of fruit produced. Yield of legumes was measured as top dry weight produced at the end of each cucurbit season.

Initial nematode populations (Pi) were determined after bed preparation but before planting, and final populations (Pf) were determined after harvest but before incorporation of plant material. A composite of 10 to 12 soil cores, 2.5-cm-d × 10 to 15 cm long, was taken from each plot. Nematodes were extracted from 100-cm^3 soil subsamples using standard sugar flotation–centrifugation techniques (9), identified to genus, and counted.

Genera were grouped into trophic groups (16), and nematode community structure was examined with hierarchical diversity indices (13). Values for Pi were pooled across all treatment plots. The numbers of nematodes in each prevalent genus and each trophic group following the intercrop (Pf) were compared using an analysis of variance (ANOVA). Diversity indices were also compared with a standard ANOVA. Nematode density data were compared separately for each intercropping system.

RESULTS

Major genera of nematodes found in each intercropping system are listed in Tables 1 and 4. Miscellaneous plant parasites found in the systems included *Criconema, Paratylenchus, Pratylenchus, Trichodorus,* and *Tylenchorhynchus.* Miscellaneous bacterivorous taxa included *Acrobeles, Cruznema, Cryptonchus,* Diploscapterinae, *Mesorhabditis, Monhystera, Pelodera, Plectus,* and *Prismatolaimus.* Predators present in the system were *Mononchus, Sporonchulus,* and *Tripyla,* and miscellaneous omnivores found were *Aporcelaimus, Discolaimus, Eudorylaimus, Mesodorylaimus,* and *Nygolaimus.*

Legume systems

Squash–legume: Under the squash–legume intercrop, there were no significant ($P > 0.10$) differences in final nematode populations among treatments for any of the nematode genera or trophic groups, based on analyses of variance (Table 1). Likewise, analyses of variance to compare community diversity showed no differences ($P > 0.10$) between treatments (Table 2).

Cucumber–legume: Under the cucumber–legume intercrop, cucumber grown in monoculture had a significantly greater number of miscellaneous bacterivores than cucumber intercropped with legumes (Table 1). Likewise, monocropped cucumber had a significantly higher final population of *Dorylaimus* spp. than cucumber grown in association with legumes (Table 1). Comparisons of community diversity showed a significantly lower generic diversity under the cucumber monocrop than under either mixed cropping system ($P \leq 0.01$). The nematode community under the hairy indigo system had a lower trophic diversity than that under the cucumber monocrop ($P \leq 0.05$). The total diversity of the community under the alfalfa system was significantly higher than that of the community under the cucumber monocrop ($P \leq 0.05$) (Table 2).

Yield response: Heavy rains during the yellow squash growing season caused severe foliar disease problems, leading to suppressed yields in all treatment plots. Yields were consistently low across all treatments, and there were no treatment differences in fruit yield, either in number of fruit or fresh weight. During the cucumber season, a significantly higher amount of fruit was produced under the cucumber monocrop than under the alfalfa intercrop treatment (Table 3). Gross profit per hectare for the production of monocropped squash was approximately 1.5 times that for the production of hairy indigo and squash, and approximately 2.4 times that for the production of alfalfa and squash (Table 3). Gross profit per hectare for production of cucumber in a monocrop system was 1.4 times higher than the profit obtained from intercropping cucumber and hairy indigo, and 2.3 times higher than that obtained from intercropping cucumber and alfalfa (Table 3). All profits are based on Honduran market values at the time of the experiment (A. Montes, pers. comm.).

Marigold systems

Squash–marigold: Under the squash–marigold intercrop, there was a significantly higher final population of *Aphelenchus* spp. than under the squash monocrop (Table 4). Trophic group diversity and total community diversity was higher under the squash monocrop than under the marigold intercrop ($P \leq 0.05$ and $P \leq 0.10$, respectively) (Table 5).

Cucumber–marigold: Under the cucumber–marigold intercrop, there were no differences in any of the trophic groups or prevalent genera (Table 4), and cropping system had no effect on community diversity ($P \geq 0.10$) (Table 5).

Yield response: Due to severe disease problems, no yield was produced during

TABLE 1. Final soil nematode densities per 100 cm^3 soil under yellow squash and cucumber monocropped (control) and intercropped with alfalfa and hairy indigo in the Yeguare Valley of Honduras, in 1991.

	Yellow squash		Cucumber	
Associated crop	Pf	Pf/Pi	Pf	Pf/Pi
	Helicotylenchus spp.			
Alfalfa	47.6	4.5	38.2	1.3
Hairy indigo	57.0	5.3	24.4	0.8
Control	44.0	4.1	61.6	2.1
Treatment comparisons	NS		NS	
Initial population (Pi)	10.7 ± 7.7		29.1 ± 24.4	
	Meloidogyne incognita			
Alfalfa	34.4	4.1	34.4	1.0
Hairy indigo	8.2	1.0	79.2	2.3
Control	8.0	1.0	9.4	0.3
Treatment comparisons	NS		NS	
Initial population (Pi)	8.4 ± 7.2		34.2 ± 34.8	
	Other plant parasites			
Alfalfa	12.6	8.4	4.4	1.1
Hairy indigo	5.4	3.6	5.4	1.3
Control	3.8	2.5	4.6	1.1
Treatment comparisons	NS		NS	
Initial population (Pi)	1.5 ± 1.6		4.1 ± 2.9	
	Aphelenchoides spp.			
Alfalfa	4.6	0.1	17.0	3.9
Hairy indigo	19.6	0.3	2.8	0.6
Control	4.6	0.1	14.8	3.4
Treatment comparisons	NS		NS	
Initial population (Pi)	63.2 ± 45.5		4.4 ± 3.9	
	Aphelenchus spp.			
Alfalfa	37.4	0.8	122.0	0.7
Hairy indigo	177.4	3.6	28.6	0.2
Control	32.0	0.6	66.4	0.4
Treatment comparisons	NS		NS	
Initial population (Pi)	49.5 ± 64.2		167.3 ± 89.3	
	Tylenchus spp.			
Alfalfa	59.2	4.5	55.4	3.8
Hairy indigo	83.0	6.3	22.2	1.5
Control	47.6	3.6	73.4	5.1
Treatment comparisons	NS		NS	
Initial population (Pi)	13.2 ± 9.3		14.4 ± 13.2	
	Cephalobus spp.			
Alfalfa	31.0	0.6	227.2	3.3
Hairy indigo	85.4	1.7	36.0	0.5
Control	19.8	0.4	110.0	1.6
Treatment comparisons	NS		NS	

TABLE 1. *Continued*

	Yellow squash		Cucumber	
Associated crop	Pf	Pf/Pi	Pf	Pf/Pi
Initial population (Pi)	50.2 ± 23.3		68.9 ± 41.9	
	Eucephalobus spp.			
Alfalfa	214.8	2.9	171.8	1.3
Hairy indigo	253.2	3.5	62.4	0.5
Control	126.0	1.7	115.6	0.9
Treatment comparisons	NS		NS	
Initial population (Pi)	73.17 ± 49.4		130.6 ± 70.3	
	Rhabditis spp.			
Alfalfa	18.8	0.0	24.2	0.3
Hairy indigo	78.8	0.1	1.8	0.0
Control	11.8	0.0	16.0	0.2
Treatment comparisons	NS		NS	
Initial population (Pi)	613.5 ± 263.4		77.9 ± 61.1	
	Other bacterivores			
Alfalfa	35.8	6.9	4.8 a	1.0
Hairy indigo	24.0	4.6	2.2 a	0.5
Control	13.6	2.6	12.2 b	2.6
Treatment comparisons	NS		$P \leq 0.10$	
Initial population (Pi)	5.2 ± 4.7		4.7 ± 2.7	
	Predators			
Alfalfa	1.2	2.4	0.2	0.2
Hairy indigo	1.2	2.4	0.2	0.2
Control	0.4	0.8	0.6	0.6
Treatment comparisons	NS		NS	
Initial population (Pi)	0.5 ± 1.0		1.0 ± 1.5	
	Dorylaimus spp.			
Alfalfa	15.2	2.1	3.4 a	0.4
Hairy indigo	36.4	5.1	5.0 a	0.6
Control	16.4	2.3	15.4 b	1.9
Treatment comparisons	NS		$P \leq 0.10$	
Initial population (Pi)	7.1 ± 5.7		8.3 ± 4.9	
	Other omnivores			
Alfalfa	6.8	9.3	0.6	0.2
Hairy indigo	7.0	9.6	0.6	0.2
Control	21.8	29.9	1.4	0.4
Treatment comparisons	NS		NS	
Initial population (Pi)	0.73 ± 1.2		4.0 ± 3.8	
	Total nematodes			
Alfalfa	522.4	0.6	703.6	1.3
Hairy indigo	836.6	0.9	270.8	0.5
Control	349.8	0.4	501.4	0.9
Treatment comparisons	NS		NS	
Initial population (Pi)	896.7 ± 394.4		548.9 ± 283.8	

Data are the means of six values. Final populations within the same nematode group with no letters or with the same letters are not different at $P \leq 0.10$.

TABLE 2. Diversity indices before planting (Di) and after harvest (Df) of yellow squash and cucumber monocropped (control) and intercropped with alfalfa and hairy indigo in the Yeguare Valley of Honduras, in 1991.

Associated crop	Yellow squash Df	Yellow squash Df/Di	Cucumber Df	Cucumber Df/Di
		Genus diversity		
Alfalfa	0.344	1.3	0.358 a	1.1
Hairy indigo	0.321	1.2	0.375 a	1.1
Control	0.294	1.1	0.275 b	0.8
Treatment comparisons	NS		$P \leq 0.01$	
Initial diversity (Di)	0.257		0.334	
		Trophic group diversity		
Alfalfa	0.457	2.0	0.266 ab	1.1
Hairy indigo	0.448	1.9	0.213 b	0.9
Control	0.518	2.2	0.296 a	1.2
Treatment comparisons	NS		$P \leq 0.05$	
Initial diversity (Di)	0.231		0.249	
		Total diversity		
Alfalfa	0.802	1.6	0.624 a	1.1
Hairy indigo	0.769	1.6	0.589 ab	1.0
Control	0.812	1.7	0.572 b	1.0
Treatment comparisons	NS		$P \leq 0.05$	
Initial diversity (Di)	0.488		0.583	

Data are the means of six values. Final diversity values within the same category with no letters or with the same letters are not different at $P \leq 0.10$.

the yellow squash season. During the cucumber season, fresh weight and number of fruit produced under the monocropped cucumber was significantly higher than that produced under the marigold intercrop ($P \leq 0.05$) (Table 6). Gross profit per hectare for the production of monocropped cucumber was more than six times that for the production of marigold and squash (Table 6).

DISCUSSION

In general, there were no consistent treatment differences in the dominant nematode genera or trophic groups under any of the four intercropping experiments. It is unlikely, however, that the communities remained constant over the course of the study because changes in such factors as soil temperatures and soil

TABLE 3. Cucurbit yield in number of fruit and fresh weight and gross profit per hectare in Honduran lempiras under different mixed cropping systems.

Treatment	Fruit yield/ha Number (×1000)	Fruit yield/ha Weight (×1000 kg)	Gross profit ha/(L)†
Legume–yellow squash intercrop			
Control (monocrop)	30.9 ± 15.3 a	4.9 ± 2.5 a	4,900
Hairy indigo	21.8 ± 16.2 a	3.1 ± 2.4 a	3,172
Alfalfa	13.5 ± 13.1 a	2.0 ± 2.2 a	2,193
Legume–cucumber intercrop			
Control (monocrop)	148.5 ± 46.2 a	23.3 ± 6.9 a	6,990
Hairy indigo	94.6 ± 43.3 ab	16.7 ± 8.7 ab	5,082
Alfalfa	59.0 ± 73.2 b	9.5 ± 9.5 b	3,043

Means in the same column with the same letter within the same experimental group are not significantly different ($P < 0.10$).
† Profits are based on Honduran market values of cucurbits and legumes in 1991. Market values: yellow squash = L 1.0/kg; cucumber = L 0.3/kg; legumes = L 0.11/kg (U.S. $1 = 5.5 L).

TABLE 4. Final soil nematode densities per 100 cm^3 soil under yellow squash and cucumber monocropped (control) and intercropped with marigold in the Yeguare Valley of Honduras, in 1991.

	Yellow squash		Cucumber	
Associated crop	Pf	Pf/Pi	Pf	Pf/Pi
	Helicotylenchus spp.			
Marigold	15.4	1.8	20.4	1.7
Control	51.8	6.2	15.4	1.3
Treatment comparisons	NS		NS	
Initial population (Pi)	8.4 ± 6.0		12.2 ± 6.7	
	Meloidogyne incognita			
Marigold	0.8	0.9	19.6	3.3
Control	38.6	42.9	25.0	4.2
Treatment comparisons	NS		NS	
Initial population (Pi)	0.9 ± 1.0		6.0 ± 5.3	
	Other plant parasites			
Marigold	7.2	3.1	10.4	1.2
Control	11.6	5.0	5.4	0.6
Treatment comparisons	NS		NS	
Initial population (Pi)	2.3 ± 2.7		8.4 ± 5.1	
	Aphelenchoides spp.			
Marigold	29.4	1.2	6.2	1.8
Control	11.8	0.5	10.8	3.1
Treatment comparisons	NS		NS	
Initial population (Pi)	24.0 ± 23.3		3.5 ± 2.5	
	Aphelenchus spp.			
Marigold	190.4	7.4	35.4	0.6
Control	104.0	4.0	34.4	0.5
Treatment comparisons	$P \leq 0.10$		NS	
Initial population (Pi)	25.7 ± 27.5		63.4 ± 25.8	
	Tylenchus spp.			
Marigold	187.6	14.0	45.6	4.7
Control	83.2	6.2	56.0	5.7
Treatment comparisons	NS		NS	
Initial population (Pi)	13.4 ± 7.6		9.8 ± 7.9	
	Cephalobus spp.			
Marigold	30.4	2.2	27.6	0.8
Control	35.4	2.6	48.4	1.4
Treatment comparisons	NS		NS	
Initial population (Pi)	13.7 ± 8.4		34.7 ± 14.4	
	Eucephalobus spp.			
Marigold	169.2	15.4	72.0	1.1
Control	94.8	8.6	65.6	1.0
Treatment comparisons	NS		NS	
Initial population (Pi)	11.0 ± 8.1		65.7 ± 59.9	

TABLE 4. *Continued*

	Yellow squash		Cucumber	
Associated crop	Pf	Pf/Pi	Pf	Pf/Pi
	Rhabditis spp.			
Marigold	40.4	0.5	9.6	0.1
Control	28.4	0.4	5.0	0.1
Treatment comparisons	NS		NS	
Initial population (Pi)	78.9 ± 57.3		75.7 ± 131.7	
	Other bacterivores			
Marigold	118.4	5.8	24.0	1.1
Control	69.6	3.4	19.0	0.9
Treatment comparisons	NS		NS	
Initial population (Pi)	20.3 ± 10.5		21.5 ± 21.2	
	Predators			
Marigold	1.6	16.0	0.8	2.7
Control	0.2	2.0	0.6	2.0
Treatment comparisons	NS		NS	
Initial population (Pi)	0.1 ± 0.3		0.3 ± 0.7	
	Dorylaimus spp.			
Marigold	4.0	0.1	8.6	2.1
Control	0.2	0.0	10.4	2.5
Treatment comparisons	NS		NS	
Initial population (Pi)	30.4 ± 16.9		4.1 ± 2.8	
	Other omnivores			
Marigold	40.6	81.2	1.6	0.6
Control	33.6	67.2	1.2	0.4
Treatment comparisons	NS		NS	
Initial population (Pi)	0.5 ± 1.1		2.7 ± 3.3	
	Total nematodes			
Marigold	835.2	3.6	281.8	0.9
Control	563.2	2.5	297.2	1.0
Treatment comparisons	NS		NS	
Initial population (Pi)	229.6 ± 123.7		308.0 ± 186.2	

Data are the means of six values. Final populations within the same nematode group with no letters or with the same letters are not different at $P < 0.10$.

moisture can cause rapid and short-term changes in soil nematode populations (6, 11,12). Still, the general consistency of the nematode communities over the course of the planting season suggests that further studies of nematode community structure and stability over time are warranted.

Many nematode species have very short life cycles and can reproduce quickly, so

TABLE 5. Diversity indices before planting (Di) and after harvest (Df) of yellow squash and cucumber monocropped (control) and intercropped with marigold in the Yeguare Valley of Honduras, in 1991.

	Yellow squash			Cucumber		
Associated crop	Df		Df/Di	Df		Df/Di
			Genus diversity			
Marigold	0.431		1.3	0.392		0.9
Control	0.411		1.2	0.403		1.0
Treatment comparisons	NS			NS		
Initial diversity (Di)		0.344			0.418	
			Trophic group diversity			
Marigold	0.362		0.8	0.239		1.2
Control	0.512		1.1	0.230		1.2
Treatment comparisons	$P \leq 0.05$			NS		
Initial diversity (Di)		0.453			0.193	
			Total diversity			
Marigold	0.793		1.0	0.631		1.0
Control	0.923		1.2	0.632		1.0
Treatment comparisons	$P \leq 0.10$			NS		
Initial diversity (Di)		0.787			0.612	

Data are the means of six values.

small changes in the soil environment can induce major shifts in community diversity (4). Likewise, shifts in diversity over the short term may be obscured in long-term studies. For this reason, a single static measurement of diversity will not give an accurate analysis of the uniformity of the community. For example, in this study, significant changes in community diversity over a 3-month period occurred as a result of slight but short-term changes in the number of nematodes in many of the trophic groups, which left the bacterivores dominating the community. However, frequent measurements of hierarchical diversity may give a good indication of the generic and trophic shifts that can occur in a community over the short term.

Although intercropping is often used by Honduran farmers in small-scale systems, large-scale intercropping appears to be an unreasonable production method. The gross economic return for cucurbits grown in the monocrop system was greater than for those grown in either the legume or marigold intercropping systems, even with the additional profit from the associated plants. The decrease in return on the cucurbits in the intercrop likely resulted from intense competition between the cucurbits and the associated plants (Powers et al., 14). Before this system can be recommended over monocropping for farmer use in Honduras, the profitability of the intercrop would need to be vastly improved.

TABLE 6. Cucurbit yield in number of fruit and fresh weight and gross profit per hectare in Honduran lempiras under different mixed cropping systems.

	Fruit yield/ha		
Treatment	Number (×1,000)	Weight (×1,000 kg)	Gross profit ha/(L)†
Marigold–cucumber intercrop			
Control (monocrop)	166.0 ± 77.5 a	24.4 ± 7.6 a	7320
Marigold	33.5 ± 26.6 b	4.0 ± 4.4 b	1200

Means are significantly different at ($P < 0.10$).
† Profits are based on Honduran market values of cucurbits and legumes in 1991. Market values: yellow squash = L 1.0/kg; cucumber = L 0.3/kg; legumes = L 0.11/kg (U.S. $1 = 5.5 L).

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