Effect of Predator Exclusion on Cassava Infested with Tetranychid Mites (Acari: Tetranychidae)

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ABSTRACT Chemical exclusion of predators with permethrin was used to test the effectiveness of the phytoseiid predator *Amblyseius limonicus* Garman and McGregor and a complex of minor predators in the biological control of tetranychid (*Mononychellus* spp., *Tetranychus* spp., and *Oligonychus peruvianus* McGregor) pests of cassava, *Manihot esculenta* Crantz. *Mononychellus* spp. and *Tetranychus* spp. populations were significantly higher and predator populations significantly lower in permethrin-treated plots than in control plots. Numbers of *O. peruvianus* were not affected by permethrin. Yield of fresh commercial roots and of dry matter was significantly higher in plots with predators than in plots where permethrin was applied every 2 wk for predator exclusion. Yields of neither fresh nor dry matter in control plots were significantly different from yields in plots that had been protected with acaricide, suggesting that predation kept spider mite populations below economically damaging levels.

KEY WORDS Arachnida, cassava, permethrin, predator exclusion

CASSAVA, *Manihot esculenta* Crantz, is the most important starchy root crop in the tropics. Although considered to be relatively pest tolerant, recent research has shown that pests that are present throughout the growing cycle (e.g., spider mites) can depress cassava yield (Cock 1985).

The tetranychid, *Mononychellus tanajoa* (Bondar), was accidentally introduced to Africa from tropical America and has spread to 21 of the 34 African cassava-growing countries (IITA 1985). The absence of natural enemies is thought to be a major factor limiting the control of *M. tanajoa* in Africa. The objective of our study was to determine the effect of natural enemies in control *Mononychellus* spp. and a related complex of tetranychids in their area of origin.

One method of evaluating natural enemies is through the use of selective pesticides. Braun et al. (1987a) showed that permethrin could be used to eliminate *Amblyseius limonicus* Garman and McGregor, the most common phytoseiid predator in cassava in tropical America (Bellotti et al. 1987). The minor predators *Oligota minuta* Cameron (Coleoptera: Staphylinidae), *Stethorus* spp. (Coleoptera: Coccinellidae), and spiders also are susceptible to permethrin (Braun et al. 1987b). Non-lethal side effects of permethrin in the cassava-tetranychid mite ecosystem such as phytostimulation and enhancement of phytophagous mite fe-

cundity were found to be of negligible importance (Braun et al. 1987b).

An advantage of selective pesticides over other techniques of predator exclusion, such as caging, is that they can be applied in large-scale field studies, permitting the use of yield as a criterion for evaluating predator efficacy. Although yield data are generally reported in studies of biological control with microbial agents, yield differences found in experiments with natural enemies of insects and mites are rarely published.

Materials and Methods

A predator-exclusion experiment was designed to measure the effect of mite predators on cassava mite abundance and on commercial fresh-root and dry-matter yield. Four cassava clones—MCol 22, CG5-79, 'Montero,' and 'Venezolana'—were planted at a density of 10,000 plants/ha in October 1984 on a farm in the arid northern coastal region of Colombia. The design was a split plot with four blocks, with clone as the main factor and pesticide treatment as the subplot factor. Each subplot contained 48 plants. The between-plot distance was 1 m. The pesticide treatments were permethrin application every 2 wk (6 g [AI]/100 liters Ambush 50; BASF, Federal Republic of Germany) for elimination of predators; acaricide treatment every 2 wk (Tedion V-18; 2,000 g [AI]/100 liters tetradifon; N. V. Phillips Duphar, Amsterdam); and an unsprayed control with natural populations of predators and phytophagous mites. A gasoline-powered

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Table 1. Overall univariate analyses from repeated-measures ANOVA for effect of clone and pesticide treatment on tetranychid mites and *A. limonicus* in cassava

Factor	df	Species							
		<i>M. progresivus</i>		<i>T. urticae</i>		<i>O. peruvianus</i>		<i>A. limonicus</i>	
		MS	F	MS	F	MS	F	MS	F
Whole units									
Block	3	0.01	0.8	0.01	0.2	0.09	0.6	0.83	0.6
Pesticide	2	0.42	23.1***	5.36	64.9***	5.92	38.0***	45.57	33.7***
Error	312	0.02		0.08		0.16		1.35	
Subunits									
Clone	3	0.46	28.2***	0.63	28.8***	0.01	0.3	12.77	45.9***
C × P	6	0.11	7.0**	0.13	6.0**	0.04	2.0	5.03	18.1***
Error	9	0.02		0.02		0.02		0.28	

a **, significant ($P \leq 0.05$); ***, significant ($P \leq 0.01$); MS, mean square.

backpack sprayer (16 liter) was used to apply pesticides as described in Braun et al. (1987a). Pesticide treatments were initiated 1,480 degree-days (DD) (16 wk) after planting. Degree-days were calculated as described by Gilbert et al. (1976), using the estimate of Keating et al. (1979) of the thermal threshold of cassava (13°C).

Because *M. progresivus* and *M. caribbeanae* McGregor are difficult to distinguish in the field, they were recorded as a single category. Likewise, *Tetranychus urticae* Koch, *T. cinnabarinus* (Boisduval), and *Oligonychus gossypii* Zacher also were recorded as a single category (referred to as *Tetranychus* spp.). *Oligonychus peruvianus* McGregor was recorded as a separate category. Densities of other cassava pests were extremely low and were not recorded. Phytophagous mites were evaluated by visually inspecting 40 leaves from the 15th node chosen at random in each subplot and recording the presence or absence of motile stages as described in Braun et al. (1987a). The youngest fully expanded leaf in the plant terminal is node 1 for the purposes of this study. The data for each subplot were expressed as the proportion of leaves infested, transformed (arcsine square root), and analyzed by repeated-measures analysis of variance (ANOVA) (SAS Institute 1985). Because the results were the same for the transformed and the original data, only the latter are presented. The predator *A. limonicus* was evaluated directly in the field by counting all stages except eggs on 20 leaves per subplot. Leaves inspected for *A. limonicus* also were randomly selected from the 15th node; however, *A. limonicus* and the phytophagous mites were sampled independently.

Sampling was begun at 1,340 DD (15 wk) after planting. Phytophagous mites and *A. limonicus* numbers were estimated every 2 wk on seven sampling dates. The first date preceded the first pesticide treatment by 1 wk. Commercial fresh-root yield in kilograms per hectare was estimated by weighing all the commercial roots from 16 central plants in each subplot 7 mo after planting. Dry-matter yield was calculated by the method of Toro & Cañas (1982). The yield data were analyzed by analysis of variance.

Results and Discussion

The effect of date was significant for all species ($P \leq 0.05$; df = 6; *M. progresivus*: Wilk's lambda = 0.227; $F = 10.8$; *T. urticae*: Wilk's lambda = 0.010, $F = 326.7$; *O. peruvianus*: Wilk's lambda = 0.003, $F = 446.5$; *A. limonicus*: Wilk's lambda = 0.124, $F = 22.4$). The effect of pesticide treatment was significant ($P \leq 0.05$) for all species for all dates after spraying started. The effect of clone was significant ($P \leq 0.05$) on all dates for *M. progresivus* and *O. peruvianus*, on all but the final date for *T. urticae*, and on all but the last two dates for *A. limonicus*. The multiple comparisons presented below are based on the overall univariate analyses from repeated-measures ANOVA (Table 1).

Clone. There were no significant differences in populations of *O. peruvianus* on different clones; however, CG5-79 had a significantly higher proportion of leaves infested with *Mononychellus* spp. ($P \leq 0.05$), the lowest mean number of *A. limonicus* per leaf, and the lowest fresh- and dry-matter yields (Table 2). 'Venezolana,' a local clone rated as resistant by farmers, was the highest yielder ($P \leq 0.05$), had the lowest populations of *Mononychellus* spp. and *Tetranychus* spp., and had significantly higher populations of *A. limonicus* than any other clone except MCol 22 ($P \leq 0.05$; Table 2). MCol 22 is susceptible to *Mononychellus* spp. and *Tetranychus* spp.; however, its fresh yield was not significantly different from that of 'Venezolana' despite supporting the greatest proportion of leaves infested with *Tetranychus* spp. This good yield performance in a susceptible clone may have been because of the relative abundance of *A. Zimonicus*.

Although *A. limonicus* prefers *Mononychellus* spp. as prey (Bellottiet al. 1987), it was least abundant on CG5-79, which had the greatest proportion of leaves infested with *Mononychellus* spp. Because phytoseiids consume partially digested plant sap that they extract from the guts of their phytophagous prey (Chant 1985), the low abundance of *A. limonicus* on CG5-79 may reflect the presence of some unfavorable host plant factor.

Predator Exclusion. Fresh- and dry-matter yields were 33 and 26% lower, respectively, in the pred-

Table 2. Effect of clone on cassava dry-matter and fresh yield and on populations of tetranychid mites and the predator *A. limonicus*.

Clone	Yield ^a		Proportion of infested leaves			
	Dry	Fresh	<i>Mononychellus</i> spp.	<i>Tetranychus</i> spp.	<i>Oligonychus</i> spp.	<i>A. limonicus</i> mean no./leaf
'Venezolana'	5,533A	15,365A	0.03B	0.24B	0.48A	0.86A
MCol 22	3,409B	10,391AB	0.04B	0.41A	0.49A	0.93A
'Montero'	3,551B	10,156AB	0.06B	0.37A	0.49A	0.25B
CG5-79	2,889B	9,375B	0.19A	0.25B	0.48A	0.20B

Means and proportions followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's test [Steel & Torrie 1980]).

^a Yields expressed as kg/ha.

ator-exclusion treatment than in the unsprayed treatment where predators were present ($P \leq 0.05$) (Table 3). The unsprayed plots had significantly higher numbers of *A. limonicus* ($P \leq 0.05$) and significantly lower proportions of leaves infested with *Mononychellus* spp. and *Tetranychus* spp. (Table 3). *O. peruvianus* was not affected by the predator-exclusion treatment (Table 2); however, no difference was expected because this mite lives under dense webbing and apparently is difficult for predators to capture. Fresh- and dry-matter yields in acaricide-treated plots were not significantly different from those in unsprayed plots (Table 3), suggesting that predators were successful in keeping mite densities below economically damaging levels. *Mononychellus* spp. and *Tetranychus* spp. infested 49 and 43% fewer leaves, respectively, in the unsprayed plots compared with the exclusion plots (Table 3); however, this result may have been influenced by a repellent effect of permethrin on these mites. Permethrin stimulates *T. urticae* dispersal away from treated areas (Iftner & Hall 1983), so some migration from treated to unsprayed plots may have occurred. A possible repellency effect of permethrin on *M. progresivus* also has been suggested (Braun et al. 1987b).

A. limonicus strongly prefers *M. progresivus* to *T. urticae* as prey (Bellotti et al. 1987), therefore, the role of *A. limonicus* in regulation of *T. urticae* in the unsprayed plots possibly was small. Minor predators such as *O. minuta*, *Stethorus* spp., and spiders, which also were eliminated by permethrin in the predator exclusion plots, may have contributed to *T. urticae* control (Braun et al. 1987b). At peak densities, *Mononychellus* spp. infested 25%

of leaves at node 15 compared with peaks of 75 and 100% for *Tetranychus* spp. and *O. peruvianus*, respectively. *A. limonicus* and generalist predators may have been responsible for confining *Mononychellus* spp. to a smaller proportion of infested leaves. In contrast, *Tetranychus* spp. (which suffered predation only by generalists) and *O. peruvianus* (which was protected from predation by webbing) had intermediate and high proportions of infested leaves, respectively, in the unsprayed plots.

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Table 3. Effect of predator exclusion on cassava dry-matter and fresh yield and on populations of tetranychid mites and the predator *A. limonicus*

Treatment	Yield ^a		Proportion of infested leaves			
	Dry	Fresh	<i>Mononychellus</i> spp.	<i>Tetranychus</i> spp.	<i>Oligonychus</i> spp.	<i>A. limonicus</i> mean no./leaf
Predators excluded	3,036A	8,965A	0.15A	0.54A	0.64A	0.03A
Acaricide (no mites)	3,982AB	11,660AB	0.02C	0.10C	0.22B	0.38A
Unsprayed (predators present)	4,525B	11,340B	0.08B	0.31B	0.60A	1.27B

Means and proportions followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's test [Steel & Torrie 1980]).

^a Yields expressed as kg/ha.

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