Impact of *Liriomyza trifolii* (Diptera: Agromyzidae) and Other Pests on Yields of Yard-Long Beans

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ABSTRACT. A series of 3 experimental yard-long bean plantings was made in successive dry seasons in Guam to determine insect impact on yield. Several different insecticides were used to to manipulate insect numbers. In all experiments, *Liriomyza trifolii* numbers were more closely correlated with yield than any other pest measured. Yield was reduced even where the seasonal mean number of *L. trifolii* mines per leaf did not exceed four. Both cowpea aphid, *Aphis craccivora*, and bean pod borer, *Maruca testulalis*, were direct pests which disfigured bean pods making them unmarketable. However, neither insect reduced total yields at infestation levels measured. Pod borer infestation levels were fairly low, with pod borers attacking no more than 12% of pods in unsprayed plots in the most infested of the 3 experiments. Aphid infestation rates also did not exceed 15% in any experiment. After the seedling stage, bean flies, *Ophiomyia phaseoli*, infesting up to 50% of the petioles had no effect on yield. Spider mites, *Tetranychus cinnabarinus* averaging up to 300 per leaflet also did not affect yield in the one experiment where mites were abundant.

INTRODUCTION

The serpentine leafminer *Liriomyza trifolii* (Burgess) has become widely spread in the world during the last 2 decades. *Liriomyza trifolii* has a wide host range, attacking a variety of vegetable crops and other herbaceous plants including yard-long beans, *Vigna unguiculata* var. *sesquipedalis* (L.) Walp. (Parrella 1987). Yard-long beans are commonly grown in the Pacific region, in part because they are more tolerant to root rot diseases than are *Phaseolus* beans and thus more adapted to the lowland tropics. They are grown to produce a fresh bean pod crop, rather than as a grain crop like most other cowpeas, *V. unguiculata*. When *L. trifolii* was accidentally introduced to Guam, leafminer infestations on yard-long bean crops became extremely high, reaching averages of 50 or more mines per leaf during certain seasons. High numbers of leaf mines had a very deleterious effect on yields (Schreiner et al. 1986). A steep decline in yield was observed at intermediate mine densities with yield response leveling off at high mine densities to a low but nonzero yield. At that time, it was impossible to control miners sufficiently enough to examine the effect of low mine density on yield. An efficient larval-pupal parasite, *Ganaspidium utilis* Beardsley, was obtained from Hawaii in 1984 and became established (Nafus & Schreiner 1989). By 1987, leafminers had become much less abundant in yard-long bean crops which were not heavily sprayed, and *G. utilis* had become a dominant parasite in the crop (D. Nafus, unpubl. data). It became apparent that a pest management program was required in this crop to prevent the destruction of leafminer parasites and consequent pest outbreaks. The following experiments were set up to quantify the effects of some of the other yard-long bean pests as a first step in developing a management program, as well as to determine the impact of leafminers on yield at low densities. Apart from leafminers, the most common arthropod pests found on yard-long bean crops on Guam are: the bean fly, *Ophiomyia phaseoli* (Tryon), which attacks stems at the seedling stage and continues to attack leaf petioles as the plant grows; the bean pod borer, *Maruca testulalis* (Geyer), which attacks flowers and pods primarily; and the cowpea aphid, *Aphis craccivora* Koch, which feeds on new growth, particularly flower buds and green pods, and also transmits a viral disease, Blackeye Cowpea Mosaic Virus (BlCMV) (Kimmons et al. 1990). Root knot nematodes also occur and spider mites are occasional pests.

Various combinations of insecticide treatments were used in an attempt to differentially manipulate the various pest species.

MATERIALS AND METHODS

Insecticide experiments

January 1988

A trial was run to compare bean yield resulting from no management actions verses management using several spray regimes for leafminer and other pests. Beans cv. Takii Red Seeded were planted 22 January 1988. Plots consisted of two 6 m long rows, 1.2 m apart. Plots were drip irrigated. Bean rows were separated by rows of sweet corn to minimize insecticide drift. Treatments were arranged in a randomized complete block design with 4 replicates. Treatments consisted of: 1) spraying once a week with fenvalerate (24 g a.i./100 l) (Pydrin®, DuPont, Wilmington, DE) for the whole growing season; 2) spraying fenvalerate (24 g a.i./100 l) weekly until the beans flowered (ca. 9 March 1988), then *Bacillus thuringiensis* (as Dipel®, Abbot Laboratories, Chicago, IL) weekly thereafter; 3) spraying dimethoate (62 g a.i./100 l) (Drexel Chemical Co., Memphis, TN) weekly for the whole growing season; 4) an untreated check. The number of mines per plot was estimated by counting the number of mines on 40 mature leaves in each plot. Samples were taken on 1 March (just before beans began to flower) and 5 April 1988. (3 weeks into the harvest period). Bean flies were sampled by examining 60 seedlings per plot ca. 3 weeks after planting and determining whether stems were mined, and by examining 60 petioles of leaves at mid-season. Yield equaled the total yield for both rows. Bean pods were harvested 3 times weekly, harvest terminating when most plots produced less than 50 bean pods per harvest. A subsample of 50 bean pods per plot was taken from each harvest, and the numbers infested with aphids and pod borers, respectively, were recorded.

December 1988

A second experimental crop was planted 5 December 1988 using the same bean variety. Plots consisted of 2 rows, 1.5 m apart and 6.85 m long, again separated by sweet corn to minimize drift. Half of the plots were drenched preplant with oxamyl (0.47 g a.i./100 l) (Vydate®, DuPont, Wilmington, DE) against root knot nematodes. In the design, 1 drenched and 1 non-drenched plot were to have been treated weekly with dimethoate (62 g a.i./100 l). However, through misunderstanding only the undrenched plots were sprayed. Thus, there were 5 replicates of 2 treatments, and 10 replicates of the plots treated with oxamyl preplant, but with no insecticide. In the second trial, bean flies were present in low numbers, less than 5% of petioles or seedlings being infested, thus were not counted. However, spider mites [primarily *Tetranychus cinnabarinus* (Boisduval)] were abundant after flowering. Densities were estimated by removing 15 leaves per plot and counting all mites on leaf undersides using a compound microscope. Root knot nematode impact was estimated by carefully digging up 2 hills of plants per plot (a total of 6 plants per plot) and estimating the percentage of the root hairs infected by nematodes. This was done towards the end of the harvest stage. *Liriomyza trifolii* mine tracks, aphids, and bean pod borers were counted as in the previous experiment except that leafminer tracks were counted every 2 weeks throughout the season. In addition, bean pod borers were sampled in the flowers, by picking 40 flowers per plot and counting all larvae found in them.

December 1989

The third experimental crop was planted 4 December 1989 with Takii Red Seeded. Plots consisted of two 7.6 m rows, 1.5 m apart, separated by sweet corn to minimize drift. There were 3 treatments. First, was a dimethoate treatment (62 g a.i./100 l) applied week-

ly from the seedling stage throughout the season. Second, was a dimethoate treatment (62 g a.i./100 l) during the seedling stage to control bean fly, and beginning 18 January 1990, when cowpea aphids were noted, weekly with malathion (375 g a.i./100 l)(Prentiss Inc., Floral Park, NY). Third, was an untreated check. Mines (counted every 2 weeks), bean flies, aphids, pod borer holes in the beans and pod borer larvae in the flowers were estimated as in previous experiments.

To determine which pest numbers were affected by the insecticides used, all 3 experiments were analyzed with an ANOVA; *post hoc* comparisons were done using Fisher's protected LSD (Statview 512+®, Abacus Concepts Inc. 1986). A multiple regression (Abacus Concepts Inc. 1986) was then run relating numbers of all the pests that were common enough to count. For each experiment, a regression relating seasonal mean number mines per leaf or aphid infestation and replicate against yield was also run.

RESULTS

Impact of pesticides on pest numbers and yield

January 1988

Insecticide treatments had a significant effect on most insect populations in the first experiment (Table 1), resulting in significantly increased yield. Mines were significantly less abundant in plots treated with dimethoate than in untreated ones, and somewhat reduced in plots treated with fenvalerate. All emerged leafminers from reared samples were *L. trifolii*. Significant differences in pest densities among treatments were found for bean flies, aphids and pod borers. Both dimethoate and fenvalerate were effective against bean flies, whereas fenvalerate and *B. thuringiensis* were effective in reducing bean pod borers. Aphids were significantly lower in the plots treated with dimethoate, and those treated with *B. thuringiensis*. Yield was significantly reduced in the untreated plots.

Table 1. Effectiveness of insecticide treatments on bean pests—January 1988.

Treatment	Mean no. mines/ leaflet	No. seedlings w/ bean flies	No. petioles w/ bean flies	% beans w/ aphids	% beans w/ borers	Yield/ 100 m (kg)
Dimethoate	4.4a	7a	2a	5a	12c	279ab
Fenvalerate	5.0ab	10ab	4a	13b	8b	317b
Fenvalerate/Dipel	6.8ab	14ab	8a	4a	2a	254ab
No treatment	10.4b	21b	19b	10b	5ab	192a
F	2.04	1.88	10.63	6.413	6.42	1.78
P	0.16	0.19	0.001	0.008	0.009	0.2

December 1988

Dimethoate significantly reduced mine densities by about half, although mine densities were low even in untreated plots (Table 2). There was a large reduction in spider mite densities in the treatments sprayed with dimethoate. Overall the difference was not highly significant ($P = 0.073$), however, Fisher's PLSD showed that plots treated with dimethoate had significantly less mites that those treated at preplant. The difference between the dimethoate and untreated plots was not quite significant ($P = 0.07$), even though there was a 90-fold difference. This result was because of large variance. The spider mites invaded from 1 side of the experimental plot from an adjacent planting, and the plots at the far end never became heavily infested. Because of the large differences among plots, spider mites were included as a variable in the multiple regression for this experiment. The ANOVA showed no differences among treatments for pod borer and

aphid infestations, although the Fisher's PLSD showed the dimethoate to be significantly effective. The incidence of root knot nematodes did not vary. Yield was significantly higher in the plots treated with dimethoate.

Table 2. Effectiveness of pesticide treatments on bean pests—December 1988.

Treatment	Spider mites/ leaflet	% roots w/nematodes	% beans w/borers	Borer larvae / 40 flwrs	% beans w/aphids	Mean no. mines/leaf	Yield / 100 row m (kg)
Dimethoate	1a	4a	6a	4.2a	1a	1.0a	302a
Oxamyl preplant	109b	11a	5ab	3.3a	3b	2.2b	239b
No treatment	93ab	13a	4b	2.6a	2ab	2.6b	216b
F	3.060	0.962	2.420	0.464	2.669	5.938	5.667
P	0.073	0.402	0.119	0.636	0.098	0.011	0.013

December 1989

Although yield was higher in treated plots than in untreated ones, it did not differ significantly (Table 3). Yields were less than half of what they had been in previous years. The experimental crop was planted in a different field than previously and this may have accounted for the reduction. Bean fly and aphid populations and the number of mines were significantly reduced by the insecticide treatments, but pod borers were not affected. It was hoped that it would be possible to reduce aphid populations while maintaining bean fly numbers by the use of malathion, but that did not prove to be the case. Both insecticides were equally effective in reducing insect numbers.

Table 3. Effectiveness of insecticide treatments on bean pests—December 1989.

Treatment	Mean no. mines/ leaflet	Mean no. petioles w/ bean flies	Borer larvae / 40 flowers	% beans w/ aphids	% beans w/ borers	Yield / 100 row m (kg)
Dimethoate	0.3a	1 .8a	0.07a	0.9a	7.1a	123a
Dimethoate / Malathion	0.5a	2.2a	0.06a	0.8a	6.4a	114a
No treatment	0.9b	19.0b	0.04a	5.7b	8.0a	102a
F	9.509	20.84	0.37	11.9	0.32	1.53
P	0.006	0.0004	0.7	0.0007	0.7	0.3

Correlations between pest numbers and yield

January 1988

Multiple regression was performed using all the insect variables counted. Replicates were also included as a variable, since the experimental plot was on a slope. In the January 1988 experiment, among all variables, only the seasonal mean number of mines per leaf approached statistical significance ($P = 0.06$) with respect to impact on yield (Table 4). Two regressions were also run, correlating leaf mine numbers with yield, and aphid infestation with yield (the latter regression was based on results of the December 1988 experiment). Using these statistics, the number of mines per leaf was significantly correlated with yield ($P = 0.012$), although the aphid infestation was not.

Table 4. Multiple regressions of insect population levels versus total yield of beans/100 m row—January 1988 experiment.

Variable	Range of variable	Parameter estimate[a]	Standard error	*t*	*P*
Intercept		453.09			
Replicate (Position on slope)	1–4	-21.04	22.71	0.926	0.4
Mean no. mines / leaflet	3.0–13.6	-29.28	13.91	2.104	0.06
% pods with aphids	3–15	-4.93	6.96	0.712	0.5
Bean fly infestation / 60 seedlings	3–37	5.39	4.13	1.306	0.2
Bean fly infestation / 60 petioles at flowering	0–28	-0.98	5.88	0.166	0.9
% pods with bean pod borer holes	1–22	0.37	3.92	0.094	0.9
Intercept		500. 16			
Replicate (Position on slope)		-38.50	15.96	2.427	0.03
Mean no. mines / leaflet		-25.42	8.69	2.925	0.012
Intercept		375.58			
Replicate (Position on slope)		-23.26	17.31	1.344	0.2
% pods with aphids		-7.24	4.05	1.790	0.1

[a] For all variables except Intercept, parameter estimates represent the Slope.

Table 5. Multiple regressions of insect population levels versus yield of beans/100 m row—December 1988 experiment.

Variable	Range of variable	Parameter estimate[a]	Standard error	*t*	*P*
Intercept		290.94			
Replicate (Position on slope)	1–4	22.06	7.90	2.80	0.016
Mean no. mines / leaflet	0.8–3.8	-24.14	12.14	1.99	0.07
% pods with aphids	0.8–6.8	-12.35	6.38	1.96	0.07
% pods with bean pod borer holes	2.2–7.8	-5.42	5.81	0.93	0.4
Beanpodborer / 40 flowers	1–11	3.40	0.14	0.70	0.5
% root knot nematode infected roots	0–32.5	-2.31	1.04	0.22	0.8
Spidermite	1–312	0.01	0.14	0.10	0.9
Intercept		231.00			
Replicate (Position on slope)		22.25	6.16	3.61	0.002
Mean no. mines/leaflet		-20.79	9.02	-2.30	0.03
Intercept		244.75			
Replicate (Position on slope)		13.33	5.46	2.44	0.03
% pods with aphids		-11.58	4.77	2.43	0.03

[a] For all variables except Intercept, parameter estimates represent the Slope.

December 1988

The seasonal mean number of mines per leaf, and aphid infested pods, had the most effect on yield ($P = 0.07$) (Table 5). Regression of leaf mines against yield and regression of aphid infestation against yield were significant ($P = 0.03$). The most abundant arthropods in the bean field were spider mites. Although some plots averaged as many as 312 mites per leaf, this had no detectable effect on yield.

Table 6. Multiple regressions of insect population levels versus yield of beans per 100 m/row—December 1989 experiment.

Variable	Range of variable	Parameter estimate[a]	Standard error	*t*	*P*
Intercept		155.36			
Replicate	1–4	-6.97	5.89	1.180	0.3
Mean no.mines/leaflet	0.2–1.3	-66.18	50.65	1.310	0.3
% pods with aphids	0.3–8.9	2.05	5.10	0.400	0.7
% pods with bean pod borer holes	4.5–10.9	1.33	3.45	0.390	0.7
Bean pod borers / 40 flowers	0–7	3.32	2.32	0.450	0.7
Bean fly infestation / 60 petioles	0–37	0.08	0.66	0.130	0.9
Intercept		150.80			
Replicate		4.60	3.80	1.190	0.3
Mean no. mines/leaflet		-45.80	14.80	3.090	0.013
Intercept		124.70			
Replicate		-1.10	4.40	0.252	0.8
% pods with aphids		-3.60	1.90	1.865	0.095

[a] For all variables except Intercept, parameter estimates represent the Slope.

December 1989

Multiple correlation showed none of the pests measured had any effect on yield (Table 6). A regression of the number of leaf mines vs yield was significant ($P = 0.013$), but a regression of aphid numbers against yield was not. In this experiment leafminer populations were very low, ranging from a seasonal average of 0.2–1.3 mines per leaf.

In overall comparisons in the multiple correlations of all pests against yield, the number of mines per leaf was the pest variable most closely related to yield. In none of the multiple correlations was the slope significant, although in 2 cases there was a greater than 90% probability that the numbers of mines were significantly correlated with yield. In all 3 experiments, a regression examining only the relationship between seasonal mines per leaf and yield was significant (Tables 4–6). In the December 1988 experiment, aphid infestations approached significance with respect to yield in the multiple correlation with all pests, and was definitely significant in the correlation ($P = 0.03$) where only aphids were examined. However, no significant regression was observed in the other 2 experiments. Coincidently, the experiment where aphids showed some possible correlation with yield was also the experiment in which aphid numbers were lowest, being present on only 7% of the pods in the most heavily infested plot.

DISCUSSION

Liriomyza leafminers have been shown to cause slowed growth or death of young plants (Elmore & Ranney 1954, Trumble et al. 1985), but for most crops it has been very difficult to associate specific levels of mining activity with reductions on crop yield (Parrella 1987). However, yard-long beans appear to be an exception. Severe yield reductions in this crop can be correlated with high leafminer populations (Schreiner et al. 1986). In the current experiments, overall analysis of the data suggested that an association between seasonal mean number of mines per leaf and yield probably exists, even for less severe infestations. In these experiments, the number of mines per leaflet reached no

higher than 12, as compared to numbers near 20 and above 50 in the previous work (Schreiner et al. 1986). Data indicating that low numbers of leafminers might affect yield were weakest for the December 1989 study, although there was some indication that leafminers had more effect than other pests. However, in this experiment the number of mines per leaf was very low, ranging from 1–4 per leaflet. Leaf mining agromyzids were not generally associated with cowpeas in the Old World. Spencer (1973) listed a number of agromyzids associated with *Vigna*, but only 1 was a leafminer. That species was found only in west Africa, where it was present in large numbers, although no information was available on how much damage it caused. The New World species *L. trifolii* was reported to have caused the near collapse of cowpea production in Tanzania after its introduction (Jackai & Daoust 1986). Economic losses from this pest have not generally been reported on cowpea crops in the New World (Jackai & Daoust 1986), but observations in Trinidad showed that yard-long beans and tomatoes were the crops most severely infested by this fly (Neuenschwander et al. 1987). Leaf mining appears to be a new type of stress for Old World cowpea crops and the impact on yield seems to be much greater than accounted for by leaf tissue loss alone. Host plant resistance to *Liriomyza* has been identified in cowpea varieties grown for seed (de Moraes et al. 1981), although it has not been sought specifically in yard-long beans, which are cowpea varieties grown for their green pods.

None of the other pests monitored in these experiments significantly impacted total yard-long bean yield at the densities in these experiments. *Aphis craccivora* is a direct pest of yard-long beans, aggregating on the pods and rendering them unmarketable. Data suggest that as long as less than 15% of tips are infested, total yield of yard-long beans will not be reduced. *Aphis craccivora* is a vector of Blackeye Cowpea Mosaic Virus on Guam (Kimmons et al. 1990). This virus has been shown to reduce yard-long bean yields on Guam (Kimmons & Wall, pers. comm.). The role of aphids in yard-long bean plantings may be more serious as vectors than as direct pests.

CONCLUSIONS

Liriomyza leafminers were the most important indirect pests of yard-long beans in the experiments undertaken in this study. Cowpea aphids and bean pod borers were important as direct pests by ruining individual bean pods for market. Further research, including information about farmer practices, is needed to evaluate their economic injury level as indirect pests. At the relatively low infestation levels observed, their role as phloem feeders or flower feeders, respectively, was unimportant in these fertilized and irrigated yard-long bean plantings. Bean flies did not affect yield in these experiments. Infestation of up to 50% of leaf petioles by bean flies was not found to be associated with loss of potential yield.

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