Enhanced *Fusarium solani* f. sp. *phaseoli* Infection by Bean Fly in Malawi

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ABSTRACT

Letourneau, D. K., and Msuku, W. A. B. 1992. Enhanced *Fusarium solani* f. sp. *phaseoli* infection by bean fly in Malawi. Plant Dis. 76:1253-1255.

Field samples of beans on subsistence farms in Ntchisi, central Malawi, showed a correlation between the incidence of *Fusarium solani* f. sp. *phaseoli* and the presence of bean fly (*Ophiomyia* complex) puparia. Exclusion experiments in the field and greenhouse measured the rate of *F. s. phaseoli* infection in beans subjected to and protected from bean fly attack. Results indicated that *F. s. phaseoli* infection was significantly higher in plants exposed to bean fly attack than in those protected from bean flies. Malawian farmers may need to alter nitrogen fertilizer practices to keep bean fly and *F. s. phaseoli* levels low.

Tropical agroecosystems, with a rich array of potential insect pests and plant diseases, warm weather to support many pest generations per year, and strong and frequent rains that leach soil nutrients and promote optimal conditions for many plant pathogens, present extremely intricate problems for pest control, yet critical information gaps exist concerning the life histories, dynamics, and interactions among many important tropical pests. This knowledge is necessary for a strategic approach to pest management, especially for farmers operating under severe economic constraints, as is the case with many subsistence farmers in tropical regions. For example, studies on insect vector movement patterns and disease incidence revealed the importance of intercropping in reducing the spread of disease in Nicaraguan maize fields (10) and Malawian groundnut (4) and bean (8) fields. Such biological information forms the basis both for development of integrated pest control strategies and for evaluation of new management practices on existing pest problems in complex systems.

Accepted for publication 3 August 1992.

Fusarium solani (Mart.) Sacc. f. sp. *phaseoli* (Burkholder) W.C. Snyder & H.N. Hans., a soilborne pathogen, first reported by Burkholder (1) as the cause of dry root rot of beans, causes yield losses worldwide (14). The fungus is not a wilt-producing organism, although mycelium frequently invades the plant's vascular system. The pathogen kills the tissue around the basal part of the stem and root system, and the characteristic symptom of damage on beans is the reddish discoloration of the taproot and the desiccated lower stem (3). *F. s. phaseoli* is a common, but yet not serious, pathogen of bean in Malawi (11).

Three species of bean fly (Diptera: Agromyzidae), *Ophiomyia phaseoli* (Tryon), *O. spencerella* (Greathead), and *O. centrosematis* (De Meijere), attack beans in Malawi, causing substantial yield losses, especially in late-planted bean (L. M. Kantiki, *personal communication*; 6). The first species deposits its eggs in leaf tissue and the larva mines the leaf, descends the stem, damages the vascular tissue, and pupates at the stem-root junction just below the soil surface (5). The latter two species oviposit in the stem or hypocotyl but damage the plant in the same way as the larvae feed and develop. The puparia are exposed in young plants and lodge in a lesion in the root or lower stem under the damaged epidermis. Heavily infested plants wither and die as water and mineral uptake is impeded. Most of the eggs are deposited in the plant within the first week after emergence from the soil, with larvae reaching the base of the stem to pupate approximately 23–30

days after foliage appears on the bean plant.

Bean fly has been shown to facilitate infection of several root and stem pathogens in pea and asparagus (7,12). Preliminary observations in Malawian bean fields have indicated that the stem-boring fly facilitates infection. The objectives of this study were to determine if the bean fly does facilitate infection of bean by *F. s. phaseoli* and if so, how significant is the interaction.

MATERIALS AND METHODS

Study sites. Initial field samples of bean (*Phaseolus vulgaris* L.) plants were taken during the 1990 dry season (May through October) in a village near Ntchisi in central Malawi. These farmers' fields are at 1,240 m elevation and receive approximately 1,085 mm of rainfall annually. Soils tend to be moderately acid (mean pH = 5.7, OM = 3.0%). Field and greenhouse experiments were done during the following wet season at the University of Malawi, Bunda College of Agriculture, Lilongwe, located at 1,116 m elevation. This area receives a median annual rainfall of 934 mm during October through April. The soils at both locations are sandy loam or loamy sand (mean pH = 6.0, OM = 2.9%).

On-farm surveys. Each of five fields in four farmers' subsistence farms at Ntchisi was divided into 10 equal subplots for a stratified random sample of incidences of bean flies and *F. s. phaseoli* infection. Five to 10 plants were uprooted within 1 m of row, randomly selected in each of the 10 subplots. A sample of 484 stems from five fields of bean plants 2.5–5 wk old were dissected to record the number of bean fly puparia and larvae and the number of diseased plants. Plants were scored as infected if the vascular tissue showed the characteristic reddish-brown discoloration caused by *F. s. phaseoli.*

Greenhouse trial. To verify a host-pathogen relationship and identify the *Fusarium* sp., a concrete slab (3 × 1 m) was filled to 15 cm with sterilized soil. The inoculum was isolated from bean plants collected from the Bunda College of Agriculture research fields in November 1990 and maintained on potato-dextrose agar. Mycelia, spores, hyphal fragments, and agar were mixed for 1 min in a blender with 300 ml of sterile water per plate, and 3 L of the suspension was applied as a drench to the soil prior to sowing beans as experimental plots.

The 3 × 1 m slab was divided into 16 equal plots, each 18.75 × 6.25 cm. Each plot was sown with 10 seeds of the bean cultivar Nasaka, which is susceptible to Fusarium root rot. Eight plots were selected randomly and covered immediately after planting by a fine mesh cage (18 × 5 × 45 cm). The other eight plots were left uncovered. The whole slab was then covered by a wooden cage of mesh and transparent plastic (3 × 1 × 1 m).

Two days before the beans emerged, 108 infested bean stems (average of four pupae per stem) were placed in the main cage. Another 250 stems (average of four pupae per stem) were added after 1 wk. Plants were uprooted after 6.5 wk to record the incidence of *Fusarium* sp. infection on plants protected from and exposed to bean fly oviposition.

Field experiment. To test for bean fly enhancement of *F. s. phaseoli* infection, 28 paired planting stations (three seeds per station spaced at 30 cm along ridges set 90 cm apart) were selected before bean emergence within a larger set of seven experimental plots designed to measure the effects of various management practices on bean fly incidence and their biological control (6). One of the paired planting stations was covered by a fine mesh bag (50 × 50 cm) supported by three stakes and tightly tied around a PVC pipe (12 cm in diameter, 18 cm deep) sunk into the soil around the seeds. Twenty paired plants were left uncovered so that the bean fly attack could take place, and eight were partially covered by PVC pipe or mesh with windows for bean fly access, or both. These bean plants were uprooted at 51 days after emergence to score for the presence of bean fly puparia and *Fusarium* sp. infection. If *F. s. phaseoli* was present but had not penetrated the stem tissue, we did not score the plant as infected. To verify these visual assessments, stems were washed, their surface tissue was removed, and cultures were made from the inner tissue for detection of *F. s. phaseoli.*

Table 1. Comparison in five farmers' fields of actual levels of infection with *Fusarium solani* f. sp. *phaseoli* and levels expected if bean fly infestation were independent of *F. s. phaseoli* infection

	Field number				
	1	2	3	4	5
Crop(s)	Bean	Bean/cabbage	Bean	Bean	Bean
Weeks after sowing	3.5	3.5	3.5	5.0	2.5
Plants per meter ($\bar{x} \pm$ SE)	33 ± 2	32 ± 2	29 ± 1	23 ± 1	37 ± 3
Number of stems dissected	62	125	98	103	96
F. s. phaseoli infection (%)	49	42	18	83	8
Bean fly infestation (%)	22	28	10	47	2
F. s. phaseoli and bean fly (%)					
Actual	20	25	10	47	2
Expected	11	12	2	39	2
Bean fly only					
Actual	2	3	0	0	0
Expected	11	16	8	8	2
F. s. phaseoli only (%)					
Actual	5	28	8	40	6

Table 2. Greenhouse and field experiments using completely randomized blocks to detect differences in infection with *Fusarium solani* f. sp. *phaseoli* among bean plants exposed to or protected from bean flies (*Ophiomyia* complex)

Experiment	Treatment	No.	Bean fly infestation (%)	Other insect damage (%)	*F. s. phaseoli* infection (%)
Greenhouse[y]	Covered	8	0	1.3 ± 1.3	41.5 ± 8.2 a
	Exposed	8	6.6 ± 3.5	1.3 ± 1.3	68.7 ± 8.2 b
Field[z]	Covered	7	1.8 ± 8.1 a	24.4 ± 7.5 a	10.7 ± 4.5 a
	Exposed	7	51.8 ± 6.4 b	20.0 ± 5.2 a	57.1 ± 5.7 b

[y] Means (± SE) significantly different if followed by different letters (ANOVA, treatment df = 1, $F = 7.3$, $P = 0.03$; block df = 7, $F = 1.6$, $P = 0.26$).

[z] Means (± SE) significantly different if followed by different letters ($ANOVA_{beanfly}$, treatment df = 1, $F = 61.6$, $P = 0.0001$; block df = 6, $F = 1.7$, $P = 0.14$. $ANOVA_{disease}$, treatment df = 1, $F = 40.8$, $P = 0.0001$; block df = 6, $F = 1.0$, $P = 0.46$).

RESULTS

On-farm surveys showed that infection with *F. s. phaseoli* was related to bean fly incidence, suggesting the existence of an insect-pathogen interaction. Given that an average of 40% (± 13% SE) of all uprooted plants were infected with *F. s. phaseoli*, we expected a similar proportion of the plants infested with bean flies to be infected by *F. s. phaseoli.* Instead, 95% of the 107 stems (of 484 dissected) with bean fly puparia at the base had *F. s. phaseoli* infections and only 5% were pathogen-free. A field-by-field survey showed a consistent trend for infection with *F. s. phaseoli* to be associated with bean fly pupae, whereas bean fly pupae occurred less often than expected in healthy plants (Table 1). The lack of independence suggested either that the bean fly can carry the fungus to new hosts or that the lesions they cause in the lower stem and upper root areas facilitate entry by the pathogen from the surrounding soil.

The infection rate in the bean plants sampled in our greenhouse trial was similar (51.2%, $n = 82$). The pathogen isolated from these plants was identified as *F. s. phaseoli*. Bean fly infestations were found in only three of the eight uncovered treatment subplots. However, plants exposed to bean flies had a significantly greater infection rate than did plants covered by mesh cages (Table 2). An increased level of infection with *F. s. phaseoli* in exposed bean plants, few of which contained bean fly pupae, suggests that under greenhouse conditions, large numbers of flies can enhance infection rates without actually causing a lesion at the base of the stem.

In our field tests, bean fly incidence had a dramatic effect on incidence of infection with *F. s. phaseoli*. Twenty-eight paired comparisons among seven plots of Nasaka beans showed that plants from which bean flies had been excluded were much healthier than those exposed to bean fly attack (Table 2). Only 4.8% of 84 plants in the experiment without visible insect damage to the stem-root junction were infected with *F. s. phaseoli*.

DISCUSSION

Results from complementary on-farm surveys and greenhouse and field experiments in central Malawi suggest that the infection of *P. vulgaris* by *F. s. phaseoli* is enhanced by a major pest of bean such as the bean fly. *F. s. phaseoli* is probably widespread in Malawi even though it has not been previously described as a major pathogen attacking bean in the region (2,9,13). Stover (11) reports that *F. s. phaseoli* has caused localized root rot outbreaks on *P. vulgaris* in Malawi and speculates that larger-scale problems are averted by the general use of land race cultivars with some resistance to the disease. We suggest that plants that are normally resistant to or escape infection by *F. s. phaseoli* may succumb to the disease when damaged by bean fly, so that the two organisms exacerbate yield losses caused by either pest individually. Attempts to select resistant or less susceptible cultivars must include a consideration of both pests.

Also, evaluation of management practices on pathogen incidence should include the intermediary role of the bean fly. For example, Letourneau et al (6) showed that increased levels of *O. spencerella* in central Malawi are associated with nitrogen fertilization in the early season. Because farmers commonly fertilize bean fields when they intercrop, complex interactions among cropping patterns and *F. s. phaseoli* may result. The integration of basic information on the interaction between these pests and pathogen into bean production strategies may help maintain the relatively minor status of *F. s. phaseoli* as a bean pest in Malawi.

ACKNOWLEDGMENTS

This research was funded with grants to the first author through the Fulbright Senior Scholars Program (CIES) for Regional Research in Sub-Saharan Africa, the Rockefeller Foundation, USAID, and the University of California Santa Cruz Academic Senate. Logistical support was provided by the Bean-Cowpea CRSP program at Bunda College of Agriculture, University of Malawi, and the Ministry of Agriculture, with field extension officer J. Singano. L. Kantiki and R. O'Malley participated in preliminary field work for this study, and F. Arias G., Y. Tembo, S. Manyera, and the late H. C. Phiri provided excellent technical assistance.

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