Response of Early- and Late-Planted Soybeans to Natural Infection by Bean Pod Mottle Virus

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ABSTRACT

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A field experiment was conducted in 1983 to measure the effect of bean pod mottle virus (BPMV) infection on yields of three cultivars of soybean (*Glycine max*) planted on 29 June. Plants were subjected to the following treatments: 1) mechanical inoculation with BPMV on 22 July, 2) natural inoculation by transmission of BPMV by bean leaf beetles, or 3) covering with window-screen cages to exclude the vector until 2 August. Yield losses of treatments 1 and 2 compared with 3 for cultivars Centennial, Davis, and Forrest were 19.2 and 15.8, 13.9 and 2.3, and 17.4 and 11.2%, respectively. Severity of symptoms and estimations of percentage of plants infected on 3 August appeared related to yield reductions. Transmission of BPMV occurred in 0.013% of seed harvested from beetle-inoculated Centennial and Forrest. In 1984, Forrest was planted on 2 May, and plots were either covered with screen cages to exclude the vector for 1 mo or exposed to beetle feeding (virus transmission). Plots in the latter treatment yielded 16.7% less than those of caged plants. Results indicate that beetle-transmitted BPMV can significantly reduce soybean yields in both early- and late-planted soybeans.

Bean pod mottle virus (BPMV) was first observed affecting soybeans (*Glycine max* (L.) Merr.) in North Carolina in 1955 by Skotland (7) and recently was reported to be the principal virus present on soybeans in 1983 in eastern North Carolina (5). In the mideastern portion of the state, the virus was found in 88% of the fields surveyed. In field experiments, soybean yield losses as high as 13% were recorded when cultivar Forrest was planted in May and inoculated with BPMV at the two- to three-leaf stage (8). In these studies, plants were mechanically inoculated with a pad inoculator (4), and an insecticide was applied biweekly to control the principal beetle vector of the virus, the bean leaf beetle (*Cerotoma trifurcata* Forst.), thus maintaining uninfected control plots. Yields of virus-infected plants varied greatly among cultivars and only infections early in plant development (before V6) had a significant effect on yield. This led the authors to suggest that soybean crops planted in late June in fields following small grain may sustain significant yield loss if grown near earlier-planted fields infected with BPMV and harboring high bean-leaf beetle populations.

Because about one-third of the soybeans grown in North Carolina are planted in late June in fields following small grain, field studies were conducted to determine the effect of BPMV on early- and late-planted soybeans when the virus is transmitted by the natural vector.

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MATERIALS AND METHODS

Experiments were conducted at the Tidewater Research Station near Plymouth, NC. Plots were planted at the rate of 21–25 seeds per meter of row in a Norfolk sandy loam soil. Each plot consisted of three rows 5.8 m long spaced 96 cm apart and was separated from the next plot by alleys 90 cm wide.

On 29 June 1983, soybean cultivars Forrest, Davis, and Centennial were planted in main plots (nine rows each) following a randomized split-plot designed experiment replicated five times. Each plot consisted of three subplots that were either inoculated with BPMV with a pad inoculator (4,8) on 22 July, or allowed to be inoculated by the natural beetle vector, or covered with a screen cage on 5 July to exclude the vector. On 18 May, soybeans in adjacent areas were planted and inoculated with BPMV on 10 and 16 June with the pad inoculator; these plants served as an inoculum source for the vectors. On 2 August, cages were removed from the plots, plants were tied up if necessary to prevent lodging, and the experimental area and surrounding soybeans were sprayed with 0.83 kg a.i./ha of carbaryl (Sevin 80WP) three times at 5-day intervals to control the beetle population and to impede virus transmission to control plots.

On 2 May 1984, soybean cultivar Forrest was planted in a randomized complete block design with 10 replicates. Treatments consisted of either plants exposed to normal beetle feeding or plants covered from 14 May until 15 June with a screen cage similar to those used in 1983. Two extra pairs of rows of soybeans were planted throughout the experiment to divide it into three equal areas; plants in these extra rows and two bordering rows on each side of the area were inoculated mechanically with BPMV on 18 May and 7 June to ensure a virus source for the vectors. No insecticides were applied until mid-August.

Cages used to cover the center rows of control plots were constructed of standard aluminum window screening with square openings of about 1.5 mm. The 122-cm-wide × 5.8-m-long material was creased in the middle lengthwise and the folded angle stapled over the top of wooden stakes driven in the middle and ends of each row to make an inverted V-shaped cage about 46 cm high and 50 cm wide at the base. Openings in the ends were closed by stapling a triangular piece of screening to the ends of the sides. The bottom edges of the cage were secured by covering them with soil.

The percentage of infected plants in the center row of each plot was estimated on the basis of the percentage of plants showing symptoms on 3 and 30 August 1983 and on 29 June 1984. In 1983, average symptom severity was also estimated for the center row of each plot on a scale of 1–5, where 1 = no symptoms and 5 = severely rugose foliage.

Soybeans were threshed from 4.9 m of the center row of each plot after removing the end plants. Seed was cleaned and weighed after a uniform seed moisture was obtained. In 1983, seed from each plot was analyzed for percent protein and oil. Data on yield were subjected to analysis of variance.

Seed harvested in 1983 from beetle-inoculated and mechanically inoculated plants was planted in the greenhouse in January 1984 to determine seed transmission of BPMV. Seedlings were examined when their first trifoliolate leaf had expanded, and sap from foliage of plants suspected of being virus-infected was assayed with agar immunodiffusion tests and indexed on the primary leaves of bean (*Phaseolus vulgaris* L.) cultivars Kentucky Wonder Pole and Pinto and on Forrest soybean.

RESULTS

1983. On 13 July, the first trifoliolate leaves were about half expanded and beetle feeding was light. On 22 July, when plants were mechanically inoculated, the beetle population had increased and feeding was prevalent. Plant growth under the cages was more rank than that of uncaged plants, and when cages were removed (2 August), some plants lodged; these plants were tied up.

On 3 August (38 days after planting), the percentage of plants infected by beetles was only slightly less than that of mechanically inoculated plants of the same cultivar; Centennial was infected more than Davis or Forrest (Table 1). Symptoms on these two cultivars were less severe than those on Centennial, and symptoms on beetle-inoculated plants of Centennial and Davis were less severe than those on mechanically inoculated plants of the same cultivar; this was most evident with Davis. On 30 August (62 days after planting), all plants in inoculated plots showed typical BPMV symptoms.

Within cultivars, yield differences between mechanically inoculated plots and the controls were greater than yield differences between beetle-inoculated plots and controls (Table 1). This effect of the method of inoculation was greatest for Davis. Yields from this cultivar inoculated with beetles did not differ significantly from those of the controls. Yields from all other virus-inoculated treatments were different from yields of the control treatment of the same cultivar.

One BPMV-infected seedling was found in each group of Forrest and Centennial when 10,377 and 4,400 seedlings, respectively, were grown from seed harvested from beetle-inoculated plots. No infected seedlings were detected of 7,260, 4,523, and 4,464 seedlings produced from seed harvested from mechanically inoculated Forrest, Centennial, and Davis, respectively. Results of analyses for protein and oil in seed of the three cultivars showed no trends of the effect of BPMV on these characters (Table 1).

1984. Primary leaves were unfolding and beetles were plentiful when the cages were erected on 14 May. The next day, plants in the cages were sprayed with carbaryl to eliminate any trapped beetles. On 2 July, 17 days after the cages were removed, virus-infected plants in plots left uncaged were plentiful, and some plants that had been caged also had virus symptoms. On 24 July, all plants appeared infected, and on 6 August, plants had ceased flowering.

Soybean yields from uncaged and caged plots averaged 3,235 and 3,887 kg/ha, respectively. This 16.7% yield difference is statistically significant at $P = 0.01$, and the coefficient of variation was 5.7%.

DISCUSSION

Because screening was used in both experiments to exclude the vector, the possible effect of this enclosure should be considered. Shou et al (6) in Ohio covered soybeans with two thicknesses of cheesecloth, reducing light by 63%, for various 2-wk periods beginning when the third trifoliolate leaf was unrolled. Seed yields from plots shaded after midbloom were significantly less than those of unshaded control plots by up to 29%. Shading before midbloom had little effect on yields. The screening used in the virus experiments allowed about 60% of light to pass and was removed 2–3 wk before flowering, hence it was not used during the period Shou et al (6) found influential in reducing yields. If shading had reduced seed yields in either experiment, the percentage yield loss of the virus-infected treatments reported here would be abnormally low.

Two principal factors in determining the yield loss caused by BPMV in soybeans are the stage of plant development when infection occurs and the percentage of the crop infected (3,8,9). The greater yield loss sustained by the mechanically vs. beetle-inoculated plants may be related to the higher incidence of infected plants in the mechanically inoculated treatments observed on 3 August. However, the incidence of plant infection based on symptoms under conditions of high vector populations is probably erroneously low since plants show no appreciable symptoms for 5–7 days after inoculation.

Yield losses caused by mechanically inoculating the three cultivars planted in late June were greater than those previously reported for these cultivars planted in May and mechanically inoculated at the V2–3 growth stage (8). In the current study, mechanically inoculated plots were also exposed to virus infection by beetles until 3 August 1984. This would reduce the number of plants that escaped infection, which assumes importance since uninfected plants of Centennial adjacent to BPMV infected plants yielded 50% more than uninfected plants in pure stands (9). The beetle-inoculated, early-planted Forrest plots sustained a yield loss almost equal to that of the mechanically inoculated, late-planted plots of 1983 and was slightly greater than that reported for this cultivar planted in May and mechanically inoculated (8). Mechanically inoculated Davis sustained a yield loss in 1983 three times greater than that reported by

Table 1. Response of three soybean cultivars to inoculation with bean pod mottle virus mechanically or by bean leaf beetle transmission[a]

Cultivar	Inoculation method	Estimated infection[b] (%)	Symptom severity score[b,c]	Yield kg/ha	Yield Loss (%)	Yield C.V. (%)	Seed Protein (%)	Seed Oil (%)
Centennial	Mechanical[d]	93	4.8	2,180	19.2		45.0	18.3
	Beetle	89	4.5	2,270	15.8	7.6	44.4	18.5
	Control	0	1.0	2,700	···		44.3	18.5
				$LSD_{0.05} = 270$			$LSD_{0.05} = NS$	
Davis	Mechanical	70	3.8	2,460	13.9		43.6	19.0
	Beetle	64	3.3	2,790	2.3	10.4	43.3	18.9
	Control	0	1.0	2,860	···		43.3	19.2
				$LSD_{0.05} = 410$			$LSD_{0.05} = NS$	
Forrest	Mechanical	78	3.9	2,120	17.4		41.5	20.1
	Beetle	76	3.9	2,280	11.2	6.4	41.9	19.7
	Control	0	1.0	2,570	···		41.9	19.8
				$LSD_{0.05} = 220$			$LSD_{0.05} = NS$	

[a] Seed planted on 29 June 1983.
[b] Readings made on 3 August.
[c] 1 = No symptoms, 5 = severe symptoms.
[d] Inoculated on 22 July.

Windham and Ross (8), whereas the yield loss of beetle-inoculated Davis was similar to that of the prior work. Seasonal variations of yield loss in response to BPMV probably reflect both variability in the infected hosts' response to the environment and/or variability in vector populations and activity. Dietz et al (1) reported three peak periods of adult bean leaf beetle activity, i.e., the end of May, the middle of July, and the second or third week of September. Responses of the beetles' life cycle to environmental events could influence population dynamics and hence could influence virus transmissions. If high feeding and flight activity coincides with the seedling stage of a crop, then frequent virus transmissions would occur at a growth stage at which virus infection will cause maximum yield loss.

The greater percent yield loss exhibited by beetle-inoculated Centennial than by Forrest may relate either to Centennial's more sensitive host reaction (higher symptom and severity score) or to its greater incidence of infection, perhaps caused by preferential beetle feeding or ease of infection at an early plant growth stage. Similarly, the 10-fold difference in Davis' yield loss between beetle-inoculated and mechanically inoculated plants appears related to the relatively low percent infection recorded on 3 August for the former treatment. Possible explanations for this are a low feeding preference by the vector or a resistance to infection exhibited by Davis.

The results of the seed transmission tests verify the report of Lin and Hill that BPMV is seed transmitted in soybean (2). The transmission rate in seed from beetle-inoculated Forrest and Centennial (0.013%) was about 1/10 that found by the above authors. If seed with this virus transmission rate were planted to give about 250,000 seedlings per hectare, the 32 virus-infected plants probably would be a sufficient virus source in the presence of a high beetle population to cause a significant yield loss.

The failure to detect any virus-infected individuals among the 16,247 seedlings derived from the mechanically inoculated plants may indicate that seed transmission is more likely to occur in seed from beetle-inoculated plants than from mechanically inoculated plants. However, with the low rate of seed transmission observed, such a conclusion is questionable.

Results from these experiments tend to support results of Windham and Ross (1), namely that BPMV "infections at the V6 or later growth stage did not appreciably affect yields." Preventing BPMV infection for about 1 mo after planting, as was accomplished with the cages, apparently delayed infection long enough to avoid a damaging infection. In areas of endemic BPMV (5) and high beetle populations early in the season, a few insecticide applications to young seedlings to control *C. trifurcata* populations (and early virus transmission) may postpone virus spread until a plant growth stage at which the virus causes little or no yield reduction.

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