Effect of Inoculation with Maize Dwarf Mosaic Virus at Several Growth Stages on Yield of Sweet Corn

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ABSTRACT

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Sweet corn cultivars Bonanza and Stylepak were planted at Landisville and Rock Springs, PA, in 1979 and 1980 and inoculated with maize dwarf mosaic virus strain A at different growth stages beginning at the three- to four-leaf stage and continuing at weekly intervals until the eight- to nine-leaf stage. There was no effect of virus infection on total number of ears or total fresh weight of either cultivar at Landisville in 1979. Both cultivars had significantly lower numbers of marketable ears and marketable fresh weight; greatest reductions occurred when inoculations were made at the eight- to nine-leaf stage. At Rock Springs, greatest reductions in marketable ears and fresh weight occurred when inoculations were made at the four- and eight- to nine-leaf stages for Bonanza and the six- to seven-leaf stage for Stylepak. In 1980, moisture was limiting through much of the season. Numbers of marketable ears were reduced when inoculations were made at the four- to five-leaf stage and beyond for Bonanza and at the six- to seven-leaf stage for Stylepak. At Rock Springs, there were significant reductions in marketable ears and fresh weight and total fresh weight for Bonanza inoculated at the five- to six-leaf stage and for Stylepak inoculated at the four- to six-, six- to seven-, and seven- to eight-leaf stages.

Maize dwarf mosaic virus (MDMV) is widely distributed in the United States (1,2,4,15). Host resistance is the preferred control for this virus in sweet corn (*Zea mays* L.) (9). The nature and type of resistance needed to reduce the impact of MDMV could be more effectively identified from information on MDMV infection as it relates to yield loss.

In dent corn, a direct relationship between yield and MDMV infection has been proposed, suggesting that greatest reductions result from early infections (three-leaf stage) (5,12). However, Rosenkranz and Scott (11) reported greater yield reductions when plants were inoculated at the five-leaf stage, although losses were associated with early inoculations. Reductions as high as 70–90% in yield of dent corn, measured as shelled grain, have been reported (5–8, 11–13). Evidence from yield loss research involving sweet corn and MDMV suggests that greater losses result from early inoculation (10).

This research was conducted to investigate the quantitative and qualitative effects of MDMV infection on sweet corn in relation to host growth stage at time of inoculation.

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MATERIALS AND METHODS

Experiments were conducted during 1979 and 1980 at Landisville and Rock Springs, PA. The same procedures were used in all experiments except where specified. Plots of sweet corn cultivars Bonanza and Stylepak were planted 8 May 1979 and 8 May 1980 at Landisville and on 14 May 1979 and 7 May 1980 at Rock Springs. Carbofuran (10G) was applied at planting at the rate of 1.12 kg a.i./ha to control insects. Experimental plots were four rows wide and 7 m long and were planted at 0.91-m row spacings. Plots were arranged in a randomized complete block design with four replicates of each treatment. Plant populations were adjusted to 20,000 plants per acre in 1979 and 15,000 plants per acre in 1980. The two center rows of each plot were inoculated and harvested.

Treatments were inoculations at weekly intervals beginning at the three-leaf stage and continuing to the eight- to nine-leaf stage. Five inoculations were made at Landisville in 1979 and six in all other instances. Plots of uninoculated plants served as controls.

Inoculations were made by hand, using gauze pads, Carborundum, and the expressed juice of Bonanza plants infected with MDMV strain A (MDMV-A) for 2–3 wk in a greenhouse. Separate sets of source plants were planted and inoculated to ensure a uniform concentration of virus for each field inoculation. Inoculum was prepared at the site by grinding 30 g of leaf tissue from source plants in a blender with 500 ml of water. The mixture was strained through four layers of cheesecloth and maintained on ice. The top three leaves of every plant in the center two rows were inoculated.

In 1979, the percentage of plants in each plot with visible symptoms was determined 1 wk before and after anthesis.

In 1980, disease incidence was assessed weekly beginning 5 wk after inoculation for a total of four and five determinations at Landisville and Rock Springs, respectively.

All primary ears in each two-row plot were harvested, husked, and classified as marketable or unmarketable based on ear size and the presence of kernels. Numbers of ears in each category were counted and weighed. Analysis of variance was performed on the number of ears and fresh weight for the total plot and marketable portion. Duncan's least significant difference was used to determine significant ($P=0.05$) differences between treatment means (3).

RESULTS

Virus infection had little effect on total number or total fresh weight of ears for either cultivar at Landisville in 1979 (Table 1). Numbers of marketable ears (ME) and marketable fresh weight (MFW) were reduced in both cultivars inoculated with MDMV-A. For the cultivar Bonanza, inoculated plots had significantly lower ME and MFW when compared with the uninoculated controls, with the greatest reduction occurring when inoculations were made at the eight- to nine-leaf stage. The inoculated plots of Stylepak also showed reductions in ME and MFW, with the greatest reduction occurring at the eight- to nine-leaf stage. There was no significant difference between the uninoculated plots of Bonanza and Stylepak for either variable.

Disease incidence was generally higher in Stylepak (36–68%) than Bonanza (9–29%). Although all plants in each plot were inoculated, total infection was not achieved, which may reflect differences in resistance within cultivars. Further, there was no correlation between disease incidence and yield; treatments with lowest ME and MFW did not have highest disease incidence. Some uninoculated plants developed symptoms,

possibly by secondary spread from inoculated plants.

Similar results were obtained at Rock Springs in 1979 (Table 2), where cooler temperatures during the growing season (1 C less than Landisville) probably slowed the growth of plants. Neither total number of ears nor total fresh weight was reduced in either cultivar inoculated with MDMV-A. There were reductions in ME and MFW in inoculated plots of both cultivars, with significant reductions for inoculations at the four- and eight- to nine-leaf stages for Bonanza and the six- to seven-leaf stage for Stylepak. Yield was generally lower at Rock Springs than at Landisville. Trends in disease incidence at Rock Springs were similar to those observed at Landisville, although disease incidence was higher at Rock Springs.

In 1980, rainfall was 5.1 cm below normal in July and August at Landisville and 6.4 cm below normal in June, July, and August at Rock Springs. The effect of moisture stress was evidenced by the low ME from uninoculated plots of both cultivars (Tables 3 and 4). There was no reduction in the total number of ears or total fresh weight for either cultivar at Landisville (Table 3). Apparent reductions in ME and MFW of Bonanza inoculated at the six- to seven-leaf, eight- to nine-leaf, and nine-leaf to tassel stages and of Stylepak at the six- to seven-leaf stage were not statistically significant. The numbers of ME in the plots inoculated earlier were slightly greater than in the uninoculated plots for both cultivars. Disease incidence was high in Bonanza inoculated at the six- to seven-leaf stage and in Stylepak inoculated at the five-leaf, five- to six-leaf, and the six- to seven-leaf stages.

At Rock Springs in 1980, significant reductions in total fresh weight, ME, and MFW but not in total number of ears occurred in Bonanza inoculated at the five- to six-leaf stage and in Stylepak inoculated at the four- to six-, six- to seven-, and seven- to eight-leaf stages (Table 4). Disease incidence was high for inoculations at these growth stages, but there was no apparent correlation

Table 1. Yield and disease incidence for plots of two cultivars of sweet corn inoculated with maize dwarf mosaic virus strain A at various growth stages at Landisville, PA, in 1979

Growth stage at inoculation	Total[a]		Marketable[a]		Disease incidence[b]	
	Ears	Fresh weight (kg)	Ears	Fresh weight (kg)	6 wk	8 wk
Bonanza						
3 to 4 leaf	54.0	11.4	15.3	4.0	20.5	21.3
5 to 6 leaf	52.0	10.9	20.3	5.1	23.0	25.8
6 to 7 leaf	51.8	11.2	18.3	4.6	27.3	29.3
7 to 8 leaf	47.0	10.4	18.5	4.8	3.0	25.0
8 to 9 leaf	50.5	9.8	8.0	2.2	1.8	9.5
Uninoculated	48.3	11.2	26.5	7.0	0	15.5
Stylepak						
3 to 4 leaf	42.3	8.0	20.0	4.7	18.5	57.5
5 to 6 leaf	53.0	10.5	25.5	5.4	13.3	39.8
6 to 7 leaf	49.3	9.6	20.5	5.1	36.0	66.3
7 to 8 leaf	46.3	9.6	24.0	6.0	57.3	68.3
8 to 9 leaf	48.5	9.3	19.0	4.3	0	56.8
Uninoculated	50.0	9.1	27.0	6.7	0	35.8
DLSD[c]	NS	NS	5.8	1.4		

[a] Values are averages of four replicates.
[b] Percentage of plants in the plot with visible symptoms 6 and 8 wk after inoculation.
[c] Duncan's least significant difference for treatment means ($P = 0.05$); NS = not significant.

Table 2. Yield and disease incidence for plots of two cultivars of sweet corn inoculated with maize dwarf mosaic virus strain A at various growth stages at Rock Springs, PA, in 1979

Growth stage at inoculation	Total[a]		Marketable[a]		Disease incidence[b]	
	Ears	Fresh weight (kg)	Ears	Fresh weight (kg)	6 wk	8 wk
Bonanza						
3 leaf	49.3	10.2	13.1	2.4	19.5	17.0
4 leaf	45.8	8.1	6.3	1.4	67.5	59.0
4 leaf	45.5	9.6	14.5	3.5	31.0	31.5
4 to 5 leaf	46.3	9.6	12.8	3.1	32.0	27.0
6 to 7 leaf	45.0	9.3	10.8	2.5	31.2	22.0
8 to 9 leaf	48.0	9.5	7.0	1.6	5.0	9.5
Uninoculated	47.0	10.1	21.3	5.1	7.5	9.5
Stylepak						
3 leaf	41.8	7.3	12.3	2.8	33.5	47.5
4 leaf	41.8	7.1	12.8	2.6	45.0	78.5
4 leaf	43.5	7.3	13.5	2.9	23.0	43.0
4 to 5 leaf	41.5	7.4	16.5	3.2	35.0	48.5
6 to 7 leaf	45.0	6.5	5.8	1.2	93.0	78.5
8 to 9 leaf	40.8	7.6	10.3	2.2	4.5	76.8
Uninoculated	42.8	8.5	18.0	4.3	7.5	16.0
DLSD[c]	NS	NS	7.7	1.7		

[a] Values are averages of four replicates.
[b] Percentage of plants in the plot with visible symptoms 6 and 8 wk after initial inoculation.
[c] Duncan's least significant difference for treatment means ($P = 0.05$); NS = not significant.

between disease incidence and yield. Disease incidence was higher in Bonanza than Stylepak for some inoculations at Rock Springs in 1980.

DISCUSSION

The relationship between MDMV infection and yield loss in sweet corn does not appear to be direct or simple. In this research, greater yield reductions occurred when inoculations were made at advanced growth stages. Also, the growth stage at which inoculations had the greater effect on yield varied by year and location. The effect of these factors may be influenced by the environment, specifically temperature. Thompson and Hebert (14) and Tu and Ford (16) reported increases in infection and symptom expression in plants inoculated with MDMV at higher temperatures. Symptoms of MDMV infection and resulting yield losses might be reduced from early inoculations because of cooler temperatures. In this research, cool temperatures at early planting (within the first 2 wk of May) may have reduced the effect of virus infection, resulting in the low disease incidences observed in early inoculations.

Previous results (10–12) suggesting a direct relationship between MDMV infection and yield of both dent and sweet corn are contrary to the data obtained in this research. These discrepancies may result from different environmental effects, primarily temperature. Our data as analyzed and presented were based on the response of a cultivar in production and not plants displaying symptoms within a cultivar (9,10), which may also contribute to differences between our and other results.

Cultivars may respond differently in terms of yield loss to infection with MDMV. In general, inoculated plots of Stylepak had higher disease incidences, whereas greater yield losses were

Table 3. Yield and disease incidence for plots of two cultivars of sweet corn inoculated with maize dwarf mosaic virus strain A at various growth stages at Landisville, PA, in 1980

Growth stage at inoculation	Total[a]		Marketable[a]		Disease incidence[b]			
	Ears	Fresh weight (kg)	Ears	Fresh weight (kg)	5 wk	6 wk	7 wk	8 wk
Bonanza								
3 leaf	48.7	9.8	14.0	3.8	0.6	6.5	7.1	0.6
4 leaf	47.7	9.7	11.7	3.3	11.6	16.7	11.2	5.1
4 to 5 leaf	46.3	8.5	9.7	2.6	21.9	21.2	21.2	16.6
6 to 7 leaf	46.7	7.9	6.3	1.6	50.6	41.3	46.5	36.3
8 to 9 leaf	43.3	8.8	6.3	2.0	0	0.7	13.4	9.9
9 leaf	44.3	7.5	5.7	1.5	0	0.7	6.6	7.2
Uninoculated	44.7	9.1	11.7	3.3	0	3.3	3.3	1.3
Stylepak								
3 to 4 leaf	43.0	7.1	11.7	2.8	6.4	4.4	6.3	4.4
4 leaf	47.0	6.8	9.0	1.9	13.1	6.5	9.9	7.2
5 leaf	41.3	6.7	5.0	1.5	39.6	34.2	36.6	27.6
5 to 6 leaf	32.0	5.5	3.3	0.7	96.5	91.6	100.0	98.6
6 to 7 leaf	35.0	5.5	5.7	1.2	0	20.6	62.1	66.6
8 to 9 leaf	38.3	7.1	9.3	2.3	0	0	17.8	14.0
Uninoculated	37.0	6.4	8.0	2.1	0	0	1.9	0
DLSD[c]	18.2	2.5	11.8	3.1				

[a] Values are averages of four replicates.
[b] Percentage of plants in the plot with visible symptoms 5, 6, 7, and 8 wk after initial inoculation.
[c] Duncan's least significant difference for treatment means ($P = 0.05$).

Table 4. Yield and disease incidence for plots of two cultivars of sweet corn inoculated with maize dwarf mosaic virus strain A at various growth stages at Rock Springs, PA, in 1980

Growth stage at inoculation	Total[a]		Marketable[a]		Disease incidence[b]				
	Ears	Fresh weight (kg)	Ears	Fresh weight (kg)	5 wk	6 wk	7 wk	8 wk	9 wk
Bonanza									
3 to 4 leaf	40.0	8.6	11.5	3.0	13.8	5.2	7.5	7.6	8.6
4 leaf	41.0	7.0	4.3	1.0	25.2	16.4	8.6	9.8	16.6
5 leaf	40.5	6.3	4.3	1.2	50.6	43.1	43.8	39.5	70.2
5 to 6 leaf	42.5	6.3	1.5	0.4	84.1	92.8	92.8	88.4	73.2
6 to 7 leaf	37.0	7.1	4.5	1.2	4.5	7.5	47.9	24.4	51.0
8 to 9 leaf	41.3	6.9	5.5	1.3	0	0	0.5	0.6	17.8
Uninoculated	42.3	8.0	7.3	1.8	1.5	0	0.6	0	8.7
Stylepak									
3 to 4 leaf	38.8	6.5	13.0	2.9	7.4	3.7	4.9	4.4	10.8
4 leaf	37.8	5.7	7.5	1.6	28.4	24.9	22.7	21.4	18.4
5 leaf	42.3	6.3	8.8	1.8	44.5	44.4	51.6	43.3	47.9
4 to 6 leaf	37.5	5.2	5.8	1.4	61.5	66.9	68.7	70.0	74.2
6 to 7 leaf	38.0	4.8	4.0	0.9	3.1	81.1	83.1	78.6	81.7
7 to 8 leaf	39.8	5.5	6.0	1.4	1.9	1.1	74.9	61.3	67.6
Uninoculated	37.5	6.6	11.8	2.8	0	0	3.1	0	4.4
DLSD[c]	9.2	1.1	5.5	1.3					

[a] Values are averages of four replicates.
[b] Percentage of plants in the plot with visible symptoms 5, 6, 7, 8, and 9 wk after initial inoculation.
[c] Duncan's least significant difference for treatment means ($P = 0.05$).

associated with Bonanza. These differences in cultivar response to MDMV-A infection may reflect tolerance. This trait, yielding well in the presence of disease, may occur in other cultivars. It is also possible that visible symptoms did not reflect the extent of infection in Bonanza, which could account for the lack of any correlation between disease incidence and yield.

Yield loss in sweet corn due to MDMV-A infection involves the interaction of several factors: host genotype, disease resistance, growth stage at inoculation, and environmental factors both before and after inoculation. Further investigation of yield loss relationship with respect to growth rate of the host may elucidate interactions among these factors.

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