Effect of Maize Dwarf Mosaic Virus Infection on Yield and Stalk Strength of Corn in the Field in South Carolina

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ABSTRACT

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Infection of two cultivars of corn (*Zea mays*) in the field by maize dwarf mosaic virus (MDMV) resulted in statistically significant reductions in yield and fewer kernels per ear when diseased plants were tagged for identification at harvest and yields and kernel numbers were compared with those obtained from adjacent "nearest neighbor" symptomless plants. All diseased plants were rated 1.4 for severity of infection; 5% of the plants of both cultivars were diseased. Yields of individual diseased plants varied widely. The severity index did not provide an accurate indication of yield. Extrapolation of yield data from individual plants indicated that an average yield reduction of 62% could occur under circumstances of 100% disease incidence. Each 1% increase in disease incidence was responsible for a loss of an average of 63 kg/ha of grain. Infection by MDMV also resulted in statistically significant reduction in stalk strength, as determined by the kilograms of force required to exceed the resistance of the stalks to bending. Stalks from diseased plants were smaller in diameter than those from symptomless adjacent plants. Stalk diameter appeared to be one factor that determined stalk strength. No stalk lodging occurred in the field.

Field surveys and transmission studies in the greenhouse during and before 1968 revealed maize dwarf mosaic virus (MDMV) in South Carolina (5; G. C. Kingsland, *unpublished*). Subsequent surveys (1,3) identified this disease on corn (*Zea mays* L.) and/or johnsongrass (*Sorghum halepense* [L.] Persoon) from at least nine counties representing all areas of the state.

Results of research concerning the effect of MDMV on yield have been published from South Carolina (4) and from several other areas. Research conducted by Schiefele (7), for example, indicated that virus-susceptible segregates of a three-way hybrid yielded 3,889 kg/ha when inoculated early (three- to four-leaf stage) with MDMV strain A. Progeny of this cross yielded 4,955 kg/ha when inoculated at a later date, when the plants were knee-high. Uninoculated check plants yielded 6,147 kg/ha. Schiefele concluded that time of inoculation was an important factor in determining the magnitude of yield reduction and that even late inoculation could result in significant yield reductions (19% in this case) in susceptible cultivars.

Scott and Nelson (8) found that per-plant yields of a MDMV-resistant by a resistant cross were reduced by 8 g when yields from the inoculated plants were compared with those from uninoculated plants in an adjacent row. A 27-g difference in yield was realized when adjacent inoculated and uninoculated rows of a MDMV-resistant by a MDMV-susceptible hybrid were compared. The yield reduction for a MDMV-susceptible by a susceptible hybrid was 47 g per plant when adjacent rows of inoculated and uninoculated plants were compared.

Rosenkranz and Scott (6) found no significant differences in height reduction as a result of inoculating two hybrids at five growth stages (third to eleventh leaf stages) with MDMV strain A. They further reported between 14 and 20% stalk lodging for the Mp490 × Mo12 cross and between 13 and 20% for Pioneer 511A, compared with 6 and 14%, respectively, for the uninoculated controls of these crosses. The differences in percentage of lodged plants among the five dates of inoculation were not statistically significant. Inoculation of the two hybrids at the three-, five-, seven-, nine-, and eleven-leaf stages resulted in yield reductions of between 5 and 28%. Largest yield reductions (17 and 28%) occurred in both hybrids when inoculated in the five-leaf stage. An average yield reduction of 36% was calculated when the observed disease incidence and yield data were used to estimate yields based on a hypothetical disease incidence of 100%.

Josephson et al (2) compared grain yields per plant of three cultivars with a graduated scale (1–9) of MDMV severity ratings. They concluded that severity ratings could be used as indicators of yield and showed that plants with the highest ratings (6 or above) suffered yield reductions of between 77 and 91% compared with the average per-plant yields of plants with a severity rating of 1. Their results further indicated that an average decrease of 44 and 86 g per plant occurred with each unit increase in disease severity rating for DeKalb 805A and Funk G-4831W, respectively.

The effect of MDMV infection on yield of corn depends on the severity of infection of individual plants, which influences the yield per plant, and on the numbers of plants infected by the virus, which determines the yield per unit area. The research reported in this article was undertaken to determine the reduction in yield of individual plants infected with MDMV, to determine the loss in yield per hectare attributable to virus infection in a known population of plants, and to extrapolate the observed virus incidence and yield values to estimates of potential yield losses, assuming 100% virus-infected plants. The relationship between MDMV infection and stalk strength also was determined.

MATERIALS AND METHODS

Field plots measuring 93 m^2 were established in corn cultivar test plots on a Varina loamy sand in Aiken County, South Carolina. The plot of McCurdy 72-44A contained seven 15-m rows of 63 plants each (47,468 plants per hectare). The plot of McCurdy 76-29 contained seven 15-m rows of 70 plants each (52,631 plants per hectare). The row width was 86 cm. Approximately 450 kg/ha of 5-15-30 fertilizer was applied at the time of planting on March 29. The plots received three cycles of overhead irrigation during June, which provided sufficient moisture for development and maturation. Johnsongrass with typical symptoms of MDMV was along the outside border of the plots, and four small local patches were within the plots.

Nineteen plants of both cultivars developed MDMV symptoms by July 12. These plants were rated for symptom severity and tagged for identification. The severity rating was on a scale of 0–4, with 0 representing no symptoms and 1–4

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representing various degrees of mosaic symptom development from 1 = mild leaf discoloration to 4 = severe mosaic pattern development on all leaves of the plant. Leaf samples of six randomly selected plants of both cultivars with symptoms were collected at time of tagging for inoculation to indicator plants in the greenhouse. Each sample was ground separately in distilled water with 3/F grit silicon carbide with a mortar and pestle. The homogenate was rubbed over the youngest leaf of 5-wk-old seedlings of nine DeKalb BR64 sorghum (*S. vulgare* Persoon) plants and nine Pioneer 3369A corn seedlings in 8-in. pots in the greenhouse.

Individual ears of the tagged diseased plants and ears of adjacent symptomless plants in the same row were harvested at late dent stage of maturity. Kernels on each ear were counted, shelled from the ear, air-dried at 25 C for 3 wk, then oven-dried for 24 hr at 35 C and weighed.

Yields (kg/ha) from symptomless plants were determined by multiplying the average grain yield per ear (0.2 kg for both cultivars) by the numbers of plants per hectare (47,468 for 72-44A and 52,631 for 76-29).

The yield per hectare at various levels of disease incidence was computed by the following procedure:

1. Total plant population per ha × disease incidence (%) = number of diseased plants per ha.
2. Number of diseased plants per ha × average per plant yield of diseased plants = yield per ha of infected plants at specified disease incidence.
3. Total plant populations per ha − population of MDMV-infected plants per ha = population per ha of plants without symptoms.
4. Population of symptomless plants per ha × average per plant yield of symptomless plants = yield per ha of symptomless plants.
5. Yield per ha of diseased plants at specified incidence of infection + yield per ha of symptomless plants = total yield per ha from symptomless plants and diseased plants at specified infection incidence.

Once the yield per hectare at an infection incidence of 1% had been computed, the following abbreviated formula of calculating yields at various levels of disease incidence was used:

1. Incidence of infection (%) × calculated loss in kg/ha (50 and 77.3 kg/ha for 72-44A and 76-29, respectively) for each 1% of plants per ha with MDMV = loss in yield of grain per ha at specified level of disease incidence.
2. Calculated yield per ha from plants without symptoms − loss in yield sustained at any given level of incidence of infection by MDMV (product of step 1) = yield per ha at specified level of disease incidence.

Potential yields at any incidence level can be calculated by the use of these formulas.

The *t* test for paired observations was used to determine the significance of the difference in the numbers of kernels, yields, and average weight per kernel between the symptomless plants and the MDMV-infected plants.

The third aboveground internode of nine 72-44A and 19 76-29 plants was cut from the stalks at harvest and held in polyethylene plastic bags at 5 C until used for stalk strength determinations. Stalk strength was measured on an Instron Universal Testing Instrument in kilograms of force required to exceed the resistance of the stalk segments to bending. The stalk strength determinations were accomplished by placing the stalk segments on two knife-edge supports adapted to rest on the load-measuring cell of the testing instrument, with 4.6 cm between the supports. The force was applied to the center of the stalk segments by a third knife-edge mounted on the load-drive head that was set to move downward at a constant rate of 2 cm/min. The force required to exceed the resistance of the stalk segments to bending was recorded on a strip chart. After stalk diameters were measured, the stalk pieces were cut lengthwise to determine whether stalk rot was present.

The paired *t* test was used to determine the significance of the difference in stalk diameters and in the resistance to bending between diseased and symptomless plants of both cultivars. The unpaired *t* test was used to determine the significance of the difference in the force required to exceed the resistance to bending of stalks above and below the mean diameters of both symptomless and diseased 76-29 plants.

RESULTS AND DISCUSSION

Virus indexing. An average of 40% of the Pioneer 3369A corn seedlings and 25% of the DeKalb BR64 sorghum seedlings inoculated in the greenhouse with homogenates of leaf samples from diseased plants developed typical MDM symptoms. Some of the indicator plants inoculated with virus extracts from each field sample developed MDMV symptoms. The average rating was 1 on both the corn and the sorghum seedlings. No symptoms developed on the uninoculated control plants.

Yield comparisons. Infection of both cultivars of corn by MDMV was responsible for a significant reduction in the numbers of kernels produced by infected plants. This resulted in significantly lower yields per plant, which were reflected in reduced yield per hectare. Average weights of individual kernels from symptomless plants were always higher than average weights of kernels from diseased plants of both cultivars (Table 1), but the differences were not statistically significant. Consequently, the number of kernels produced appeared to be the major component of individual plant yield.

Ears from symptomless 72-44A plants produced an average of 663 kernels per ear (k/e) weighing 200 g, compared with an average of 330 k/e weighing 94 g from diseased plants (Table 1). Ears from symptomless 76-29 plants yielded an average of 707 k/e weighing 201 g, compared with 211 k/e weighing 54 g from diseased plants. Some ears from infected plants of both cultivars produced only a few kernels. The differences in numbers of kernels and yields between symptomless and infected plants of both cultivars were significant ($P = 0.01$). The difference in yield between infected 72-44A plants and 76-29 plants was significant ($P = 0.05$).

Conversion of the yields per plant to yield per hectare revealed an average combined yield from both cultivars of

Table 1. Average number of kernels per ear, grams of grain per ear, and grams per kernel of corn from paired McCurdy 72-44A and 76-29 symptomless plants and plants infected with maize dwarf mosaic virus

	72-44A			76-29		
Measurement	**Infected**	**Symptomless**	***t***	**Infected**	**Symptomless**	***t***
Kernels/ear (no.)	330	663	7.25**	211	707	9.07**
Weight/ear (g)	94[a]	200	16.40**	54[a]	201	10.82**
Weight/kernel (g)	0.290	0.309	1.30 NS	0.262	0.285	1.03 NS

[a] $t = 2.56$* for the difference in yield between 72-44A and 76-29.

Table 2. Grain yield, loss in yield, and percentage of loss from McCurdy 72-44A and 76-29 plants without symptoms of maize dwarf mosaic virus compared with three incidence levels of infection, extrapolated from data from paired plants in field plots

	72-44A			76-29		
Incidence of infection (%)	**Yield (kg/ha)**	**Loss (kg/ha)**	**Loss (%)**	**Yield (kg/ha)**	**Loss (kg/ha)**	**Loss (%)**
0	9,494	0	0	10,579	0	0
1	9,444	50	0.5	10,502	77	0.7
5	9,244	250	2.6	10,192	387	3.6
100	4,562	4,932	52.0	2,842	7,737	73.0

Table 3. Stalk diameters and force required to exceed resistance to bending of stalk segments from McCurdy 72-44A and 76-29 symptomless plants and plants infected with maize dwarf mosaic virus

	72-44A			76-29		
Measurement	**Infected**	**Symptomless**	***t***	**Infected**	**Symptomless**	***t***
Stalk diameter (cm)	1.9	2.3	5.80**	1.8	2.3	4.67**
Force (kg)	24.6	40.7	3.77**	23.9	38.9	2.64*

Fig. 1. Ears from a symptomless McCurdy 76-29 corn plant (left) and from three plants (right) rated 1.4 for severity of maize dwarf mosaic virus infection.

Table 4. Force (kg) required to exceed resistance to bending of stalks from McCurdy 76-29 symptomless plants and plants infected with maize dwarf mosaic virus with stalk diameters above and below the means of paired-plant populations from the field

Stalk diameters	Symptomless plants	Infected plants
Above the mean	51[a]	32[b]
Below the mean	28[a]	18[b]

[a] $t = 3.74$**.
[b] $t = 2.64$*.

10,036 kg/ha from symptomless plants. The yield average was 3,702 kg/ha when calculated on the basis of an incidence of 100% virus-infected plants. This was equivalent to an average reduction in yield of 6,334 kg/ha (63%).

Symptomless 72-44A plants yielded an average of 9,494 kg/ha. The yield of 72-44A with a disease incidence of 5%, as determined by counts of diseased plants, was 9,242 kg/ha (a loss of 250 kg/ha, or 2.6%). The yield calculated on the basis of 100% MDMV incidence was 4,562 kg/ha (a loss of 4,932 kg/ha, or 52%) (Table 2). The average yield of symptomless 76-29 plants was 10,579 kg/ha. The yield of 76-29 with a disease incidence of 5% was 10,192 kg/ha (a loss of 387 kg/ha, or 3.6%). The yield of 76-29 based on 100% MDMV incidence was 2,842 kg/ha (a loss of 7,737 kg/ha, or 73%) (Table 2).

Each 1% increase in disease incidence resulted in a 50 kg/ha loss in yield for 72-44A and a 77.3 kg/ha loss in yield for 76-29.

Disease severity ratings did not provide an accurate indication of the effect of virus infection on grain yields. Wide variations in yields of both cultivars were recorded for individual plants, all rated 1.4 for severity of MDM symptoms. Yields of 72-44A, for example, varied between 2.2 and 181 g per plant. Yields of diseased 76-29 varied between 2.2 and 200 g per plant (Fig. 1). The wide variation in yields of plants with a uniform MDMV severity rating may be partially attributable to infection of the plants at different stages of development. Schiefele (7) reported that early infection of corn by MDMV may result in greater losses in yield than late infection.

Stalk strength comparisons. Stalk strength determinations with the Instron Universal Testing Instrument showed that the stalks from symptomless plants were stronger (as indicated by the kilograms of force required to cause bending failure of the stalk) than stalks from MDMV-infected plants (Table 3). Stalks from symptomless plants also were larger in diameter than those from diseased plants. The stalks of both symptomless and diseased plants of 76-29 with diameters greater than the mean were stronger than stalks with diameters below the mean. Stalk diameter appeared to be one factor that determined stalk strength (Table 4).

Although the stalks of MDMV-infected plants were smaller in diameter and weaker in terms of the kilograms of force required to cause bending failure than stalks of symptomless plants, no stalk lodging occurred in either cultivar. Differences in stalk strength between MDMV-infected 72-44A plants and adjacent paired symptomless plants were not of sufficient magnitude to permit evaluation by a stalk lodging rating index, based on attempts to physically lodge, or break, the plants in the field.

Rosenkranz and Scott (6) found that infection of Pioneer 511A by strain A of MDMV did not contribute significantly to lodging. Inoculation of Mp490×Mo12 at five growth stages resulted in an average of 17% lodging, compared with 6% for the uninoculated plants. Their general conclusion was that there was no significant difference in the amount of lodging among the groups of plants of both hybrids inoculated at different stages of growth. Other authors (2,7,8) have not referred to stalk rot or stalk lodging in their research, although this charactertistic would be readily observed in most field plot research if MDMV does, in fact, contribute significantly to lodging. Apparently, either MDMV does not predispose corn to lodging or it contributes to lodging only in a minor or secondary way under most field circumstances. No symptoms of stalk rot developed in any of the stalks from this study.

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