Maize Dwarf Mosaic Virus: Effect of Time of Inoculation and Symptomatology on Performance of Sorghum (*Sorghum bicolor*)

M. M. JARJEES and J. K. UYEMOTO, Department of Plant Pathology, Kansas State University, Manhattan 66506

ABSTRACT

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Two near-isogenic sorghum (*Sorghum bicolor*) inbreds, Combine Kafir 60 (CK60) and Kansas line 56 (KS56), were inoculated with maize dwarf mosaic virus strain A at three plant-growth stages. These inbreds differed in their responses to viral infections; under cool temperatures, CK60 developed tissue necrosis (red leaf disease) and KS56 a mosaic symptom. Results showed statistically significant yield losses with all virus treatments compared with their respective controls. At the earliest growth stage, yields of inoculated CK60 and KS56 were reduced 61 and 26%, respectively.

In the United States, maize dwarf mosaic virus (MDMV) was recognized in the mid-1960s as an economic pathogen of corn (*Zea mays* L.) (7) and sorghum (*Sorghum bicolor* (L.) Moench) (13,17). MDMV infections of these plants occur annually in major U.S. crop-growing regions. Disease symptoms in susceptible plants vary considerably and are dependent on virus strain, plant genotype, and temperature. In sorghum, leaf mosaic and/or necrosis (red leaf disease) of various plant parts may be produced (5,6). The latter condition is induced when infected plants are exposed to ambient temperatures of about 16 C or below (3,12; J. P. Snow, *unpublished*). Although effects of MDMV on sorghum yields have been published (1,2,8,10), we report the effect of different inoculation times and symptom types on performance of two near-isogenic lines.

MATERIALS AND METHODS

Plot design and cultural practices. Two near-isogenic sorghum inbreds, Combine Kafir 60 (CK60) and Kansas line 56 (KS56), were planted on 12 June 1980 and 7 June 1981 at the Rocky Ford Research Farm in Manhattan, KS. These inbreds were selected because both show mosaic symptoms in response to MDMV strain A, but under cool temperatures, CK60 also exhibits red leaf disease. A split-plot design was used consisting of four replicates of each inbred inoculated 20, 40, and 50 days after sowing. These times approximated, respectively, collar of fifth leaf visible, final leaf visible in whorl, and boot growth stages (15). Subplots consisted of an inbred line planted in four rows (9 m long and 0.75 m between rows), and the inner two rows were either inoculated or used as uninoculated controls. Outer rows served as buffers between subplots. Seedlings were thinned to one per 10 cm of row (about 131,000 plants/ha).

Fertilizer (112 kg N/ha and 22.4 kg P/ha in 1980 and 89 kg N/ha in 1981) and herbicide liquid atrazine (2.24 kg a.i./ha in both years) were applied before planting. At seeding time, soil insecticide carbofuran (1.12 kg a.i./ha in both years) was applied. In 1981, plants were sprayed twice with carbaryl (1.9 L a.i./ha) for control of chinch bug (*Blissus leucopterus* Say). Because of the drought in 1980, the plot was irrigated four times. In both years, plants were cultivated when 4–6 wk old and grain was harvested after physiological maturity (early October).

Inoculation procedure. A culture of MDMV-A was provided by D. T. Gordon (OARDC, Wooster, OH). Virus was increased in inbred corn (N28Ht) or sorghum (DeKalb E59+) and 16–21-day infected tissues were extracted in sodium citrate buffer (0.05 M, pH 7.5) containing 0.1% 2-mercaptoethanol (1:10, w/v) (14). After cheesecloth filtration, Carborundum (12 g/L, 600-mesh) was added to the extract.

Inoculum was sprayed with a DeVilbiss spray gun (model EGA-502; DeVilbiss Company, Somerset, PA 15501) onto terminal leaves of sorghum plants. Air pressure of 5.62 kg/cm^2 was supplied by CO^2 gas cylinders.

Plot surveys. Plants were inspected weekly for symptoms and enzyme-linked immunosorbent assays (ELISA) (4) were done to determine inoculation efficiency and intraplot spread of MDMV. For ELISA tests at 3–4 wk postinoculation, 20 plants from each treated and control subplot were sampled (portions of terminal leaves were excised from five contiguous plants per subplot treatment). Leaf tissues were extracted in ELISA buffer (4). Antisera against MDMV-A and strain B (MDMV-B) were prepared in our laboratory.

Before harvest in 1980 and 1981, heights of 40 plants (10 per replicate) from brace roots to flag leaf collar were determined. During and after harvest, head number and weight and grain yield were recorded. These values were taken from plants in the inner 6 m of two rows of each replicated treatment. Yield was adjusted to 12.5% moisture.

Statistical analysis. Comparisons were made within and between inbred lines by Fisher's least significant difference test at the 5% level of probability (9).

RESULTS

Symptomatology. Nearly all plants (95–100%) inoculated 20 days after planting developed prominent mosaic symptoms within 10 days of inoculation. In addition, CK60 developed severe red leaf symptoms 18 (1980) and 11 days (1981) after inoculation. Plants inoculated 40 and 50 days after planting showed milder forms of mosaic (KS56) or red leaf disease (CK60). Infection incidence ranged from 17.5 to 77.5% (means of 1980 and 1981 values). Intraplot spread of virus was detected only in the 40- and 50-day control subplots and at levels of 2.5 to 10%. All infections were MDMV-A; no MDMV-B was found. Ambient temperatures that followed all inoculations were conducive for red leaf development in infected CK60 plants. For 20-day inoculations, average minimum temperatures above 24 C conducive for mosaic symptoms were recorded 17 (1980) and 10 days (1981) after inoculation. Temperatures dropped below 18 C thereafter and throughout all 40- and 50-day inoculations and incubation periods (16).

Statistical analyses. For plant height, head number, head weight, and grain yield, statistical analyses of year by inbred by time of inoculation showed no significant interaction between years and treatments. Data reported hereafter were based on analyses of means recorded for both years.

Average plant heights of 79 and 78 cm (CK60) and 67 and 71 cm (KS56) for inoculated and control, respectively, were significantly different between inbred lines but not between treatments within inbreds (LSD values were 4.9 between treatments and 5.9 between inbreds).

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Table 1. Effect of time of inoculation with maize virus strain A (MDMV-A) on grain yield of two sorghum (*Sorghum bicolor*) inbreds during 1980 and 1981

Treatment	Plant age (days after planting)[x]	Grain yield (kg/ha)[y]	
		CK60	KS56
MDMV-A	20	1,729 h	3,221 g
	40	3,949 ef	4,115 cdef
	50	4,022 def	3,764 f
Control	20	4,478 bcd	4,358 bcde
	40	5,023 a	4,685 ab
	50	4,543 abc	4,345 bcde
LSD ($P = 0.05$)	1[z]	411	411
	2	506	506

[x] Age of plants when inoculated with virus.
[y] Each value is a mean of shelled grain yields (adjusted at 12.5% moisture) for 1980 and 1981.
[z] 1 = differences between inoculated and control or between inbreds at same age at inoculation. 2 = differences within and between inbreds at different ages at inoculation. Means followed by the same letter are not significantly different ($P = 0.05$) according to Fisher's least significant difference test.

Number of heads in inbred KS56 was not affected by inoculation; average head number was 107 (inoculated) and 114 (control). In CK60, average head number for inoculation treatments (106) was significantly different from controls (121). Values between inbreds and among like treatments, however, were not different. LSD values were 10.5 between treatments and 12.2 between inbreds.

Head weights at all inoculations except CK60 at 50 days were significantly lower than their respective controls. Also, grain yields in all inoculation trials were reduced when compared with controls (Table 1). Yields of both inbreds at 20-day inoculation were significantly different from each other and from other inoculation times, which were statistically similar (Table 1).

DISCUSSION

MDMV infection of young plants (20 days old) caused greatest yield losses. Grain yields of 40- and 50-day-old inoculated plants also were reduced compared with those from uninoculated controls, confirming previous findings that early season virus infections cause severe crop losses (1,2,8,10). In addition, our study showed that earliest infections (20 day) reduced yield significantly more in a red leaf responding inbred (CK60) than in a mosaic responding one (KS56); there were no differences between inbreds at 40- and 50-day inoculations. These results partially answer the sorghum question posed by Teakle and Moore "...of whether greater losses occur in crops planted to necrotic reactors or in crops planted to mosaic reactors" (11).

Although reductions in plant heights have been reported in virus-infected sorghum (3,8,10), none was found with the inbreds used in this study. This discrepancy may be attributed to use of different sorghum genotypes, virus cultures, and/or environmental regimes under which tests were conducted.

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