Disease Control and Pest Management

Cultural Practices and the Incidence of Sorghum Downy Mildew in Grain Sorghum

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ABSTRACT

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Several cultural practices that reduce the incidence of sorghum downy mildew (SDM) in grain sorghum were evaluated in field and greenhouse studies. Growth of oats, barley, flax, sudangrass, or cowpea for 15 days and maize for 17 days in soils infested with *Peronosclerospora sorghi* significantly reduced SDM inoculum potential. The results suggest merit for short-term crop rotations. Deep-plowing of infested plant residue with a moldboard plow reduced the incidence of infection within the field and significantly increased the grain yield of a commercial hybrid incurring >20% infection with conventional plowing. Delaying planting until April reduced the incidence of disease in two hybrids in a 1979 field test.

Additional key words: disease control, soilborne pathogens, *Sorghum bicolor*.

The increasing expense of applying pesticides and inorganic fertilizer and a desire to preserve lands from the destructive effects of heavy pesticide use have renewed interest in improving the traditional cultural methods of crop rotation and biological pest control. Crop improvement programs established during the last 20–25 yr have resulted in considerable progress in developing improved cultivers with disease resistance, but genetic resistance is not always a panacea. The vulnerability of major crop species to pathogens has been demonstrated repeatedly (3). Current trends in disease control involve managing pathogen populations by integrating genetic resistance with prudent use of chemicals and cultural practices.

Sorghum downy mildew (SDM), a disease of *Sorghum* spp. and *Zea mays* L. caused by *Peronosclerospora sorghi* (Weston & Uppal) C. G. Shaw, is presently managed by using resistant cultivars (9,13). An experimental systemic fungicide has effectively protected sorghum and maize from infection in preliminary tests (8,14). Several cultural practices have been proposed to supplement or replace chemical and genetic control of SDM, including: physically removing the soilborne inoculum (oospores) from the infection courts (7); crop rotation, which appears promising since germination of soilborne oospores can be stimulated by nonhost crops (11); and planting on dates that avoid periods favorable for infection (1,5). The purpose of this study was to evaluate the effects of tillage, crop rotations, and date of planting on reducing SDM incidence in grain sorghum.

MATERIALS AND METHODS

Tillage. The tillage experiments were conducted in Victoria and Nueces Counties in Texas during the normal cropping seasons in 1970 and 1974, respectively. Soils in these areas are fine-textured with a high clay content. Both fields were previously cropped in grain sorghum and had a history of uniformly high SDM. The two tillage treatments evaluated at each location were: conventional tillage and deep-plowing. The conventional tillage practice for grain sorghum culture in South Texas can best be described as bedding and rebedding in which the upper 10–15 cm of soil are blended, furrowed, and shaped in raised beds. Fertilizer is applied to the soil before planting (60-30-0 at the rate of 36 kg/ha in our tests) and weeds are controlled with pre-emergence herbicides and with cultivation as necessary during the growing season. Deep-plowing differed from conventional tillage in that fall plowing was to a depth of 25–30 cm perpendicular to the crop rows. The deep-plowing operation was performed with an Atlas Riverside Moldboard plow (Towner offset disc type). Following the 1969 summer harvest, old stalks were shredded, turned under, and incorporated into the soil by plowing and disking operations. The following spring, rows were formed and beds shaped. Treatments were replicated twice with deep-plowed plots of 13,000 and 10,000 m^2 alternated with control plots (conventional tillage) of 5,000 m^2 in the 1970 experiment. Half of each plot was seeded with cultivar NK265, a SDM-resistant commercial grain sorghum hybrid; the other half was seeded with NK275, a SDM-susceptible hybrid, similar to NK265 in yield potential and maturity.

In the 1974 experiment, control plots remained unplowed until

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spring and were compared with the deep-plowed treatment previously described. Deep-plowed plots 900 m^2 were replicated three times and arranged alternately with two unplowed plots of 450 m^2. The SDM-susceptible sorghum hybrid, ATX399 × TX2536, was seeded with 102-cm row spacing in all plots. Fields used for the 1970 and 1974 experiments had uniform plant densities and were treated uniformly throughout the growing season with weeds controlled as necessary.

The incidence of SDM was determined in the fields by counting the systemically infected plants within a stand of 300 plants when the crop was at the fourth-leaf stage. Grain yields were determined in 1970 from the sorghum heads harvested from 5 m of each of 16 rows per plot. At plant maturity (approximately 14% grain moisture) heads were harvested, threshed, and the grain was weighed. Yields were calculated in kilograms per hectare.

A soil bioassay was used to evaluate inoculum potential in soil furrow slices from each plot by sampling the upper 5 cm, and from 10–15 cm deep. Deeper excavation was difficult in the clay soil, and subsurface samples 15–25 cm deep were obtained only from the unplowed plots of the 1974 experiment. Each soil sample for bioassy consisted of bulked, thoroughly mixed soil from the designated strata of three furrow slices. The soil was air-dried and ground. A thermostatically controlled water bath (Wisconsin-type tank) was used to regulate the soil temperature of samples contained in sealed metal trays in the greenhouse. Each tray held approximately 2,200 cc of soil seeded with test cultivars. Two SDM-susceptible cultivars, TX414 in 1970, and TX412 in 1974, were sown 2.5-cm deep in soil sampled from the test plots. The soil was seeded with 50 and 20 seeds of the respective cultivars and maintained at 26 C. Trays were watered with distilled water daily or twice daily as required to prevent the soil surface from drying. Leaves were expanded enough to clearly distinguish diseased from healthy plants 17 days after seeding. Infection was expressed as the percentage of plants with systemic symptoms (%SDM) unless otherwise designated. Analysis of variance was performed on data from soils in tillage experiments.

Crop rotations. A soil sample was collected from the upper 15 cm of a field in Bee County. The field, characterized as sandy clay loam, was previously cropped to grain sorghum with a high incidence of SDM.

A greenhouse experiment was conducted in which SDM-resistant and SDM-susceptible maize hybrids were used as precrops. These were followed by the SDM-susceptible indicator sorghum, TX412, seeded as in the soil sample bioassay previously described. Trays were immersed in four water baths maintained at 19, 22, 25, or 28C for the duration of the experiment. Treatments consisted of soil as described; soil in which SDM-susceptible maize, TX508, had been seeded, grown for 17 days, and removed; and soil in which SDM-resistant maize, TX601, had been seeded, grown for 17 days, and removed. Each tray was immediately reseeded with 20 TX412 seeds planted 1 cm deep. Each treatment was replicated four times at each temperature. The percent SDM was determined 17 days after the second seeding.

A second precropping experiment utilized 10 cultivars of field crops of diverse genera (see Table 3). Each precrop, replicated in two trays, was seeded, grown for 15 days at 26C, and removed. Some remnant roots remained in the soil for the second seeding. Immediately following removal of the first crop, 25 seeds of the indicator sorghum, TX412, were seeded per tray. The percent SDM was determined in precropped soils and compared with percent SDM in the original field soil. Pairwise comparisons were made among data means according to Duncan's new multiple range test.

Date of planting. Two planting dates, 8 March and 15 April 1979, were compared in a field with a history of high levels of SDM in Calhoun County, Texas. A late-maturing Texas Agricultural Experiment Station (TAES) experimental hybrid and medium late-maturing commercial grain sorghum hybrid, cultivar Dorado M (Asgrow Seed Company), were replicated three times and six times, respectively, at each planting date. Plots, which consisted of 9 m rows 102-cm apart, were completely randomized. Conventional tillage and fertilization were practiced throughout the growing season. The percent SDM in each row was recorded prior to anthesis. At plant maturity (approximately 14% moisture in grain) heads from 4 m within each row were harvested for calculation of grain yield in kilograms per hectare.

TABLE 1. Distribution of sorghum downy mildew inoculum[a] in three soil strata for deep-plowed versus conventional tillage and unplowed treatments

	Infected seedlings in soil bioassays (%)			
	Victoria Co. site[b]		Nueces Co. site[c]	
Soil depth	Deep-plowed soil	Conventional tillage	Deep-plowed soil	Unplowed soil
0– 5 cm	2.5	33.8	0.9	40.1
10–15 cm	13.9	10.2	···	···
15–25 cm	···	···	18.7	1.3

[a] Based on percentage of infected sorghum seedlings in a greenhouse soil sample bioassay.

[b] TX414 used as indicator in bioassay.

[c] TX412 used as indicator in bioassay.

TABLE 2. Effect of tillage treatments on yield and sorghum downy mildew (SDM) levels in two sorghum hybrids field tested at Victoria, Texas

	SDM (%)		Yield (kg/ha)	
Tillage	NK275	NK265	NK275	NK265
Conventional	39.9*[a]	13.3	4,550*	5,300
Deep-plowed	8.1	6.7	5,700	5,600

[a] Asterisk (*) indicates statistically significant F-values ($P = 0.05$); ANOVA was conducted separately on means of percent SDM and yield.

TABLE 3. Effect of 15 days growth of 10 field crops on sorghum downy mildew (SDM) inoculum levels in naturally infested soil in a greenhouse bioassay[y]

Preceding crop species	Common name	Cultivar	% SDM in sorghum bioassay
Avena sativa L.	Oats	Ora	7.2 a[z]
Gossypium hirsutum L.	Cotton	TM-1	14.9 ab
Hordeum vulgare L.	Barley	Luther	7.2 a
Linum usitatissimum L.	Flax	CI 1789	4.2 a
Pennisetum americanum (L.) K. Schum.	Pearl millet	RMP-1	10.7 ab
Secale cereale L.	Winter rye	Elbon	27.7 ab
Sorghum bicolor (L.) Moench	Sudangrass	Haygrazer	5.6 a
Triticum aestivum L.	Wheat	Agent	16.7 ab
Triticum aestivum L.	Wheat	Little Club	19.1 ab
Vigna unguiculata (L.) Walp.	Cowpea	Calif. Blackeye	5.6 a
Vigna unguiculata (L.) Walp.	Cowpea	Burgundy pea	8.4 a
Zea mays L.	Maize	TX601	15.0 ab
Control (no crop)			42.2 b

[y] Inoculum levels estimated by percent disease in susceptible TX412 sorghum seedlings grown in the soil.

[z] Values, means for two replications, followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's new multiple range test.

RESULTS

Tillage. Inoculum potential was reduced in surface soil by deep-plowing, but was increased in lower layers of soil (Table 1). Deep-plowing reduced inoculum potential of the surface stratum when compared with that of unplowed soil in Nueces County (1974) and with conventional tillage in Victoria County (1970).

Yield of NK275 (SDM-susceptible) but not NK265 (SDM-resistant) was significantly increased by deep-plowing (Table 2). Disease incidence in NK275 but not NK265 was significantly reduced by deep-plowing.

Crop rotations. Inoculum levels in soil were reduced significantly by preplanting to *Z. mays* in greenhouse experiments (Fig. 1). Soil temperatures in these experiments appeared to have little or no effect on infection of sorghum. The susceptible and resistant maize hybrids showed no significant difference in their ability to reduce inoculum levels when evaluated by our soil bioassay method. *Avena sativa* L., *Hordeum vulgare* L., *Linum usitatissimum* L., *Sorghum bicolor* (L.) Moench, and *Vigna unguiculata* (L.) Walp. significantly reduced percent SDM in the soil bioassay (Table 3).

Date of planting. Both the SDM-resistant TAES hybrid and SDM-susceptible Dorado M incurred relatively less disease and higher yields from late planting, 15 April 1979 (Fig. 2). Mean percent SDM for the TAES hybrid was reduced from 16.5 to 2.3% while mean grain yields were increased from 1,517 to 1,725 kg/ha by late planting. Grain yield of Dorado M increased from 644 kg/ha in the early planting to 1,907 kg/ha in the late planting and mean percent SDM was reduced from 79.9% in the early planting to 21.8% in the late planting.

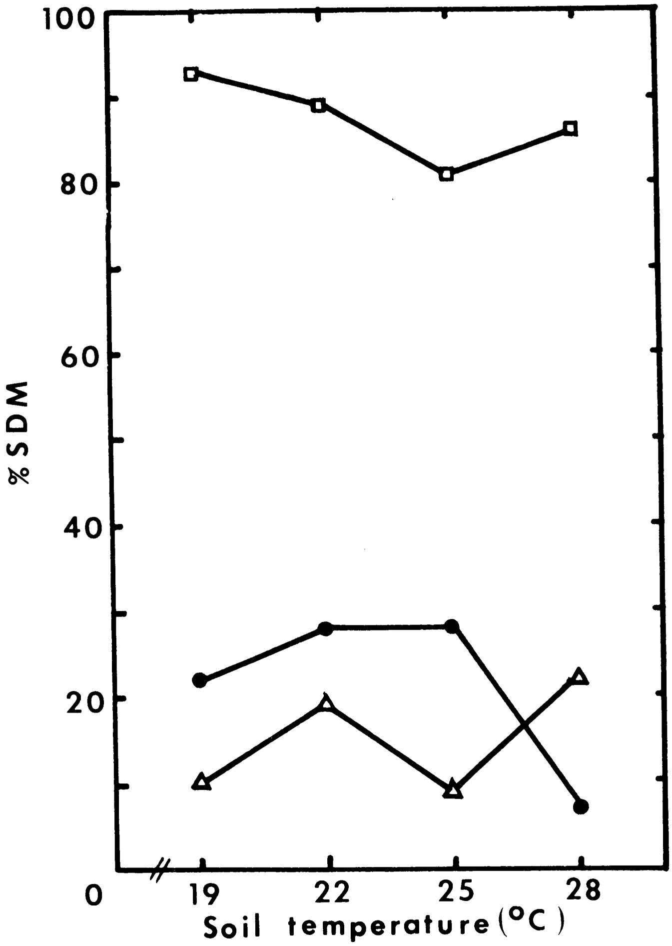

Fig. 1. Sorghum downy mildew inoculum levels (indicated by %SDM in a bioassay with seedlings of the susceptible sorghum, TX412) for naturally infested soil (□——□), naturally infested soil precropped for 17 days with an SDM-susceptible maize cultivar (•——•), and naturally infested soil precropped for 17 days with an SDM-resistant maize cultivar (Δ——Δ) at four soil temperatures in a greenhouse.

DISCUSSION

Tillage practices which leave large quantities of plant residue undisturbed in the field from time of harvest until shortly before planting the same field with the same crop are being used extensively (4) in spite of the fact that they are implicated as contributing to epiphytotics of several soilborne diseases, including SDM (2,6). It is unlikely that deep-plowing will replace present practices, because the increased cost must be balanced with economic return from a crop with reduced disease. However, where SDM is a severe problem and resistant hybrids are not available, deep-plowing can reduce disease levels and increase grain sorghum yields.

Our experimental design could not separate reduced SDM inoculum levels from other factors affecting the grain yield in deep-plowed plots, but increased yields were correlated with reduced inoculum levels as measured by our soil bioassay. Amount of disease is not always related to inoculum levels in soilborne diseases (10), but Pratt and Janke showed that the incidence of infected seedlings in the field correlates rather well with SDM oospore densities (12). This relationship is consistant with the results of our experiments where deep-plowing appeared to redistribute inoculum into lower (15–25 cm) soil strata. The appearance of a low level of infection in seedlings planted in unplowed soil from this depth suggests the presence of inoculum from years prior to the previous crop or from contamination. Inoculum from the previous crop should remain on the surface until tillage turns it under. Oospores in soil, the principal overseasoning propagules of *P. sorghi*, appear to be relatively short-lived survival structures. The inoculum potential of field soil has been demonstrated to persist for <3 yr at 22 C and >3 yr at 1 C in vitro (6), but the pathogen's rate of attrition in nature is not known. It is unlikely that oospores buried by deep-plowing can germinate near enough to susceptible sorghum seedlings to infect them.

Our observations of nonhost crops suggest that rotation might greatly reduce SDM problems in fields that have been continously cropped to grain sorghum. The ability of these crops to reduce inoculum potential may be due to stimulation of oospores to

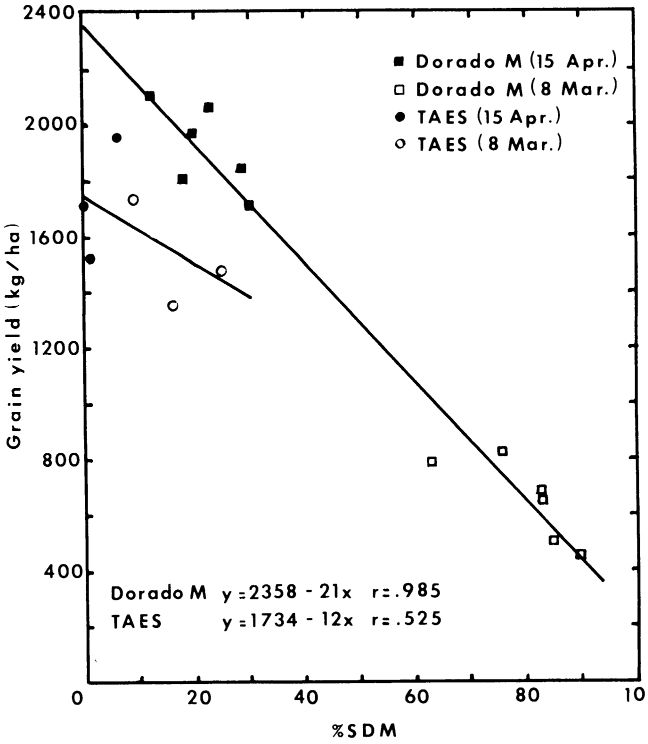

Fig. 2. Regression of grain yield on disease incidence (percent sorghum downy mildew infection) for Dorado M and a Texas Agricultural Experiment Station (TAES) experimental hybrid seeded 8 March 1979 and 15 April 1979 at Calhoun County, TX.

germinate in the absence of a susceptible host.

Grain sorghum in Texas Gulf Coast counties is generally planted between 10 March and 30 April with 50% of the crop planted between 20–30 March (15). Our tests demonstrate that seeding later than this reduces the incidence of disease (Fig. 2).

No significant increase in yield could be associated with deep-plowing in 1974 in Nueces County. Although the soil assay suggested inoculum levels adequately high for disease development (Table 1), <2% SDM was observed in this field (16). Presumably the environment suppressed infection here. Yield reductions, if they occur, are not easily measured in grain sorghum incurring <20% SDM. We have noted in other field tests, a threshold disease level below which no measurable yield loss is likely to occur. Fig. 2 depicts this disease-yield relationship occurring at approximately 8% SDM. In crop rotation, partial reduction of the soilborne inoculum may reduce the incidence of disease below the economic threshold. Sorghum hybrids with high levels of SDM resistance can similarly reduce inoculum potential and be more practical than a nonhost in areas where sorghum is continuously cropped.

The economics of crop management will dictate whether or not these cultural methods should be used to control SDM. These studies suggest that there are methods that can reduce the disease in grain sorghum. However, a greater understanding of the epiphytology of SDM is needed. Such knowledge can be used to modify and adjust these practices in reducing losses from SDM.

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