Chemical Control of Seedborne Fungi of Sorghum and Their Association with Seed Quality and Germination in Puerto Rico

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ABSTRACT

Hepperly, P. R., Feliciano, C., and Sotomayor, A. 1982. Chemical control of seedborne fungi of sorghum and their association with seed quality and germination in Puerto Rico. Plant Disease 66: 902-904.

Fusarium (mostly *F. moniliforme*), *Curvularia* (mostly *C. lunata*), and *Alternaria* sp. were the most commonly isolated fungi from Capitan sorghum (*Sorghum bicolor*) seeds produced under humid tropical conditions in Mayaguez, PR. Seedborne incidences of *F. moniliforme* and *C. lunata* were negatively correlated ($P = 0.01$) with seed germination ($r = -0.97$ and -0.63, respectively) and positively correlated ($P = 0.01$) with visible seed damage ($r = 0.92$ and 0.84, respectively). Seedborne incidence of *Alternaria* sp. was not associated with germination or seed damage ($r = -0.26$ and -0.28, respectively). Weekly applications of benomyl plus captan (0.5 + 0.5 kg/ha) from boot stage to physiologic maturity completely controlled *F. moniliforme* and significantly ($P = 0.01$) reduced *C. lunata*. Besides reducing fungal infections, fungicide applications increased seed yield, 100-seed weight, and germination.

Sorghum (*Sorghum bicolor* (L.) Moench) is an important source of food, feed, and forage (10). In Africa and Asia, it serves as a staple food for more than 200 million people. Sorghum acreage is only surpassed by rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and corn (*Zea mays* L.) worldwide.

In the United States, sorghum is grown in subhumid areas where production of corn is risky due to possible drought (10). Sorghum is more drought tolerant than corn because of its greater efficiency in water use and greater ability to recover after damage by drought. Because sorghum grows better than corn under adverse soil, climatic, and management conditions, development of this crop can greatly help developing countries feed themselves.

In Puerto Rico, imported feedstuffs support a large milk, poultry, meat, and pork industry. Increasing local feedstuff production would increase the local economy more than increased imports. Sorghum would make an attractive feed crop based on its high yield (7), versatility in cropping systems, and drought tolerance.

Previous studies in Puerto Rico indicated that bird attack and moldy seed may be limiting factors in local sorghum production. In Puerto Rico, methiocarb, a carbamate insecticide, was tested as a possible bird control (6). Although methiocarb application did not significantly reduce yield losses or feeding by birds, it did improve germination of harvested seeds. It was suggested that methiocarb might have some undescribed fungicidal action that resulted in increased germination.

The objective of these studies was to investigate the effects of seedborne fungi on sorghum seed in Puerto Rico and the possible role of the methiocarb insecticide and benomyl, captan, and thiram fungicides for their control.

MATERIALS AND METHODS

Test of seed treatments for direct fungicidal activity. To test for direct action of methiocarb as a fungicide, two seed lots of sorghum, both with high percentages of seedborne fungi and low in germination, were dusted with the following chemicals at the rate of 2.5 g a.i./kg seed: methiocarb [4-(methylthio)-3,5-xylyl methylcarbamate], Mesurol 50 WP (Mobay Chemical Co., Fern Park, FL); captan [*N*-((trichloromethyl)thio)-4-cyclohexene-1,2-dicarboximide), Captan 50 WP (Stauffer Chemical Co., Westport, CT)]; and thiram [bis(dimethylthiocarbamoyl)disulfide], Arasan 50 Red (E. I. du Pont de Nemours & Company, Wilmington, DE).

Seeds were treated in lots of 100 g or were not treated, and four replicates were placed on moist cellulose pads or on 1.5% water agar at 95% relative humidity and 25 C. Treatments were arranged in a randomized complete block design in the germinator and incubator, respectively. After 1 wk, counts were made for germination, numbers of fungi, and presence of mites. These determinations were made under the stereomicroscope at ×20. Data were analyzed for variance, and means were separated by Fischer's least significant difference (FLSD).

Field testing. A randomized complete block design with four replicates was used to test the effect of methiocarb and fungicide applications on quality and germination of sorghum. The sorghum cultivar Capitan (Asgrow Seed Co.) was sown at approximately 20 seeds per meter, and stands were later thinned to six plants per meter. Rows were separated by 1 m, with each experimental plot consisting of three 3-m rows. The treatments were as follows: a) no treatment (unsprayed control), b) methiocarb sprayed weekly at 1 kg/ha from boot stage to physiologic maturity (insecticide alone), c) benomyl plus captan sprayed weekly at 0.5 + 0.5 kg/ha

Table 1. Seed germination and incidences of fungi and mites on sorghum seeds that were either treated or not treated with standard fungicides or methiocarb insecticide[w]

	Seed lot 1			Seed lot 2		
Treatment	Germination (%)	Fungi (%)	Mites (%)	Germination (%)	Fungi (%)	Mites (%)
Not treated	52	100 a[x]	19 a	37 a	93 a	26 a
Methiocarb[y]	48	100 a	0 b	33 a	88 a	0 b
Captan[y]	53	25 b	1 b	49 b	36 b	3 b
Thiram[y]	51	10 c	19 a	48 b	21 b	21 a
NS[z]						

[w] Based on eight 100-seed replicates per treatment. Evaluations were made after 7 days of incubation at 95% relative humidity and 25 C.

[x] Means in a column followed by a common letter are not significantly different at $P = 0.01$ using Fischer's least significant difference.

[y] Applied at 2.5 g a.i. per 1 kg of sorghum seed as a dust seed treatment.

[z] No significant difference based on F value from the analysis of variance.

Accepted for publication 19 January 1982.

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0191-2917/82/10090203/$03.00/0

Table 2. Effects of foliar sprays of methiocarb insecticide, fungicide, and their combinations on fungi on seed and on yield of Capitan sorghum[x]

Treatment	Seeds with fungi (%)			Seeds damaged (%)	Germination (%)	Yield (g)	
	Fusarium	*Curvularia*	*Alternaria*			Five plants	100-seed
Not treated	62 a[y]	59 a	6 a	36 a	29 a	69 a	2.6 a
Methiocarb[z]	32 b	64 a	7 a	25 b	60 b	72 a	2.9 a
Benomyl + captan[z]	1 c	29 b	8 a	11 c	87 c	90 b	3.8 b
Insecticide + fungicide	1 c	25 b	9 a	11 c	85 c	93 b	3.6 b

[x] Harvested 7 days after physiologic maturity in Puerto Rico in 1980. Treatment means are based on four 100-seed lots.
[y] Means in a column followed by a common letter are not significantly different at $P = 0.01$ using Fischer's least significant difference.
[z] Sprays applied at 1 kg/ha or 0.5 + 0.5 kg/ha weekly from boot stage to physiologic maturity.

from boot stage to physiologic maturity (fungicide alone), or d) the separate application of treatments b and c to the same plot (insecticide plus fungicide).

Five random plants in the middle row of each plot were harvested 1 wk after physiologic maturity. Yield, seed quality, and the fungi on the seed were determined.

After panicles were dried to 12% moisture at 40 C, seeds were threshed and cleaned. Yield was expressed on a per plot basis, and 100-seed samples were taken for determining seed size. Data was analyzed for variance and treatment means were separated by FLSD.

Seed quality was scored by counting the number of misshapen and moldy seeds. Four groups of 100-seed samples per treatment were inspected under the stereomicroscope at ×20. Covariance of germination rates and estimates of damaged seed (y variables) with populations of seedborne fungi (x variable) were determined using linear correlation analysis. Treatment means were separated by FLSD, and statistical significance of the linear correlation coefficient was determined by the *t*-test.

Table 3. Linear correlation of sorghum seed germination and damage with seedborne incidence of various fungi[y]

Fungi	Seed germination		Seed damage	
	r	*t*	*r*	*t*
Fusarium	−0.97	16.3**[z]	0.92	8.8**
Curvularia	−0.63	3.1**	0.84	5.7**
Alternaria	−0.29	1.0	−0.28	1.1

[y] Linear correlation coefficient (*r*) and *t*-test (*t*) of *r* are based on sixteen 100-seed lots of sorghum incubated on potato-dextrose agar.
[z] ** = Correlation significant at $P = 0.01$, $t = 2.9$.

RESULTS

Seed applications of captan and thiram fungicides reduced fungus infections in both seed lots used (Table 1). Methiocarb did not decrease fungus infection. Both methiocarb and captan controlled the grain mite (*Acarus siro* L.) associated with the seed lots; however, thiram provided no control of these common mites in the seed lots.

Field sprays with methiocarb reduced the incidence of *Fusarium moniliforme* Sheldon in seed but not those of *Curvularia lunata* (Wakker) Boedijn or *Alternaria* sp. (Table 2). *F. moniliforme* was the dominant species of *Fusarium*. A low frequency of *F. semitectum* Berk. & Rav. and *F. roseum* var. *longipipes* Ellis & Everhart was also found. Fungicide alone or insecticide plus fungicide completely controlled *Fusarium* spp. and significantly reduced the incidence of *C. lunata* on seed. The sprays had no effect on incidence of *Alternaria* sp. Seed damage and germination were not different for the treatment of fungicide alone compared with the insecticide plus fungicide treatment. Both of these were superior to the insecticide alone (methiocarb) treatment. Insecticide alone, however, was lower in seed damage and higher in germination than the untreated control. The yield and 100-seed weight of the fungicide alone treatment were not different from those of the insecticide plus fungicide treatment. Both of these treatments were superior to the insecticide alone or the untreated control. The insecticide alone and untreated control were not significantly different in yield or 100-seed weight.

Both seed germination and damage were highly correlated with seedborne incidence of *F. moniliforme* and *C. lunata* but not with that of *Alternaria* sp. (Table 3).

DISCUSSION

Few studies have been published on sorghum seed molds and their control in Puerto Rico. Our studies focused attention on the extreme vulnerability of this crop to seed-mold fungi under the humid tropical conditions prevalent here.

Of the fungi studied, *F. moniliforme* appeared most often associated with seed damage and losses in germination of sorghum. Neergaard (5) ranked *F. moniliforme* as a major cause of sorghum disease worldwide; however, there are few detailed estimates of the losses caused by this pathogen. Leukel and Martin (3) found *F. moniliforme* as the chief cause of damping-off of sorghum in Texas. Besides controlling *F. moniliforme,* fungicide applications were associated with increased seed size and yield in these studies.

Methiocarb, a broad-spectrum carbamate insecticide, significantly reduced *F. moniliforme* seed infections but not those of *C. lunata* or *Alternaria* sp. Because the same chemical showed no in vitro fungitoxicity, we suggest that control may be related to control of insect damage (possible infection sites) or control of insect vectoring. Hsi (1) reported insect wounds as principal entry sites for the *F. moniliforme* stalk-rotting fungus in New Mexico. In Puerto Rico (2), *F. moniliforme* has been found internally in corn earworm (*Heliothis zea* Boddie) and in sugarcane borer (*Diatraea saccharalis* (Fabricius)). The sugarcane borer has been the common stalk borer of sorghum in Puerto Rico. Windels et al (11,12) reported a high incidence of *F. moniliforme* borne in picnic beetles (*Glischrochilus quadrisignatus* Say) colonizing seed in ears of corn but not in soil. The insectborne and seedborne nature of *F. moniliforme* may both be important in the development of effective control measures. Tarr (8) has suggested residue destruction, seed treatment, rotation, and injury avoidance as control measures for *F. moniliforme* seed mold and stalk rot. Based on our studies, we suggest that appropriate fungicides and insecticides should also be considered for use under humid tropical conditions, especially if seed is produced for future planting.

A previous hypothesis that methiocarb could cause increased sorghum germination by possessing some undescribed fungitoxic activity was refuted. Methiocarb, a carbamate insecticide (9), has no strict chemical relationship to the carbamate fungicides (4). Although no fungicidal action was noted, during our test the acaricidal activity of methiocarb was evident. Grain mites associated with seedborne fungi were effectively controlled on sorghum without affecting the fungi on the seed. Methiocarb may be an effective aid for cultivating fungi from field materials heavily infested with mites.

Besides *F. moniliforme, C. lunata* was associated with losses of germination and seed appearance. Compared with *F. moniliforme, C. lunata* was only partially controlled by benomyl plus captan applications.

Alternaria sp., although fairly common, had no apparent association with either reductions in germination or seed appearance. The possible manipulation of this organism as an antagonist to either *C. lunata* or *F. moniliforme* should be investigated in further works.

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