Sorghum rust. III. Losses in hybrids under semi-arid conditions[1]

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ABSTRACT

During the summer of 1986, experiments were conducted under semi-arid conditions in Southwestern Puerto Rico to evaluate yield losses in grain sorghum inbred lines (TAM428 and SC307, moderately resistant and susceptible to rust, respectively) and forage sorghum hybrids (Haygrazer and FS25A, moderately and very susceptible to rust, respectively). A split plot design was used in which half of each plot was sprayed with triadimefon (0.5 kg/ha) at boot stage followed by an application of oxycarboxin (1.0 kg/ha) 2 weeks thereafter, and the other half was nontreated (control). In all sorghum entries, except TAM 428, yields increased significantly (P = 0.05) with fungicidal rust control over those of nontreated plots. When treated with triadimefon and oxycarboxin, FS25A, Haygrazer, and SC307 showed 23, 16, and 39% greater yield than respective nontreated plots. Rust control increased 100-seed weights over the nontreated controls by 19, 25, and 45% for the respective varieties. Nonsignificant increases in seed density (approximately 5%) were found in the fungicide treatment in all lines. TAM 428, which did not respond to rust control, had over 75% functioning leaf area at physiological maturity (PM). In FS25A, Haygrazer, and SC307, all of which had less than 70% functioning leaf area remaining at PM, yield increased with increasing levels of functioning leaf area after fungicide treatment (r = 0.62*). Use of an eradicant nonpersistent rust fungicide (triadimefon) followed by a persistant systemic rust fungicide (oxycarboxin) gave excellent sorghum rust control during the critical stages for sorghum seed development. One-time use of different classes of fungicides should reduce development of fungicide resistant rust populations.

RESUMEN

La roya del sorgo. III. Pérdidas en los híbridos bajo condiciones semiáridas

Durante el verano de 1986 se realizaron experimentos de campo en la región semiárida del suroeste de Puerto Rico para determinar las pérdidas causadas por la roya en líneas de sorgo graníferos y forrajeros. Se utilizaron las líneas mejoradas para grano TAM428 y SC307, y los híbridos de sorgo forrajero Haygrazer y FS2SA, que son moderadamente susceptibles y muy susceptibles a la roya, respectivamente. Se usó un diseño de parcelas divididas; la mitad de cada parcela se asperjó con triadimefon (0.5 kg./ha.) en la época en que las plantas presentaban las hojas banderas y 2 semanas después se asperjó el follaje con oxycarboxin a razón de 1.0 kg./ha. La otra mitad de la parcela no se trató. En las líneas de sorgo utilizadas, excepto TAM428, los rendimientos aumentaron sig-

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nificativamente (P = 0.05) en FS25A (23%), Haygrazer (16%), y SC307 (39%), cuando las plantas se trataron con los fungicidas. Al controlar la roya, aumentaron los pesos de 100 semillas de FS25A (19%), Haygrazer (25%) y SC307 (45%) en relación a ios testigos no tratados. En todas las líneas de sorgo tratadas la densidad de las semillas aumentó en un 5% aproximadamente, pero no hubo diferencias significativas al compararlas con las no tratadas. No se observó respuesta al controlar la roya en la línea TAM428, la cual presentó un área foliar sana de 75% en su madurez fisiológica; mientras que Haygrazer, FS25A y SC307 presentaron menos de 70% de área foliar sana en su madurez fisiológica. Hubo una correlación significativa (r = 0.62*) entre el rendimiento de genotipos y el aumento del área foliar sana debido al tratamiento con fungicidas. El uso de un fungicida que erradique no persistente para la roya (triadimefon), seguido por un fungicida sistémico persistente (oxycarboxin) fue un excelente control de la roya durante los estados más críticos del desarrollo de la semilla de sorgo. El uso de diferentes clases de fungicidas para combatir la roya puede minimizar el riesgo de desarrollar poblaciones de roya con resistencia a los fungicidas con acción específica.

INTRODUCTION

Until recently, little experimental information has been available relating to rust severity to agronomic performance of sorghum. Some researchers believed sorghum rust was not important (9, 10, 14) whereas others believed it caused economic losses in their areas (1, 2, 3, 11, 12). Viewpoints were not based on controlled experiments.

Since 1985, field experimentation has been conducted to determine the effects of rust on susceptible and resistant sorghum inbred varieties in Puerto Rico (7, 8). In these studies, rust susceptible grain sorghum inbreds showed 20 to 60% yield increases when rust was chemically controlled. Those studies focused on the northwest sub-humid sector of Puerto Rico without testing sorghum hybrids.

Despite progress in understanding the relation of rust to sorghum inbred performance (7, 8), the effects of rust on sorghum in semi-arid environments and hybrid reactions to rust are unknown. Brandyopadhyay (1) suggested cool humid tropical zones favor rust while temperate semi-arid areas were less suitable for the pathogen. Because sorghum inbreds develop slower, yield less, and are more susceptible to stress than most sorghum hybrids (13), they might react differently to rust than sorghum inbreds.

For these reasons, sorghum rust losses were evaluated on sorghum hybrids and inbreds under semi-arid conditions in southwestern Puerto Rico.

MATERIALS AND METHODS

We used two forage sorghum hybrids, FS25A (DeKalb Seed Co., very susceptible to rust) and Haygrazer (ATX623 X Greenleaf, Taylor Evans Seed Co., moderately susceptible to rust), and two grain sorghum inbreds (SC307 and TAM 428, moderately susceptible and resistant to rust, respectively). Rust classifications were based on previous evaluations of rust pustule frequency and size observed in northwest Puerto Rico. All genotypes were photoperiod insensitive; however, forage sorghums were tall and grain sorghums were dwarf.

The Lajas Research Center of the University of Puerto Rico College of Agricultural Sciences Experimental Station was the experimental site. The prevailing local environment is hotter and drier than Isabela, Puerto Rico, where previous rust evaluations were conducted. Mean annual precipitation is approximately 1 m in Lajas, compared to 1.6 m for Isabela, and high monthly mean temperature in Lajas reaches 31.4° C, compared to 29.4° C in Isabela. The soil is highly fertile (cation exchange capacity >40 meq/100 g soil) Fraternidad clay (Udic Chromusterts, very fine, montmorillonitic, isohyperthermic) with a pH of approximately 7. Rust is found year-round on rust susceptible genotypes and on wild sorghum within and around the Lajas Research Center.

Sorghum was planted in mid-May and harvested in mid-September 1986. Lines were planted by hand at a rate of 1 g of seed per linear m of row and thinned to approximately 12 to 15 plants/meter/row. Rows were on 1 m centers. A split plot design with 4 replications was used. Main plots were sorghum entries, and sub-plots were foliar rust fungicide treatment or nontreated control. Each sub-plot consisted of four 5-m rows.

Fungicide treatments were applied with a backpack hand sprayer under low pressure. Spray continued until droplets coalesced and drained from foliage. Rust control treatment consisted of an application of 0.5 kg/ha triadimefon (Bayleton 50W, Mobay Chem. Co.)[3] at boot stage and one application of 1.0 oxycarboxin (Plantvax 75W, Uniroyal Chemical Co.) 14 days thereafter. Fungicide treatment was restricted to the center 2 rows of the sub-plots to avoid interplot interference. Rust was assayed with a modified Petersen scale (5 points) with 5 as 100% rust saturation and approximately 25% foliar coverage by pustules. Grey leafspot was rated by the 5-point Frederiksen scale (6). Six random plants were bagged at anthesis to prevent bird predation, observed periodically for disease ratings, and harvested for yield. Disease severity was noted at boot stage and until physiological maturity (PM). At PM, total foliar areas were noted and the percentage functional leaves were calculated by (FL/FL + NL) (100), where, FL = functional green non-diseased leaves and NL = necrotic non-functional leaf area.

[3]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment of materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference ofer other equipment or materials.

Mature panicles were hand harvested, dried under forced air at 35° C, threshed and weighed. From each sub-plot, four 100-seed samples were randomly collected and 100-seed weights determined. Dry seed density was calculated from volumetric measurement of 100-seed samples at 100-seed weight in grams/100-seed volume (cc).

RESULTS

Effects on Seed Production

Rust fungicide treatment significantly increased seed yield in Haygrazer (15.8%), FS25A (22.8%), and SC307 (38.9%) (tables 1 and 2). Yields with fungicide treatment were 3,694, 3,230, 2,493, and 2,475 kg/ha for TAM428, FS25A, Haygrazer, and SC307, respectively. Differences for seed yield were closely associated with differences in 100-seed weights (table 1 and 2). Losses in 100-seed weight from rust were 19.0, 25.0 and 45.0 % for FS25A, Haygrazer, and SC307, respectively. Weight for 100-seed was highest in TAM428 (2.3 g) and lowest in Haygrazer (1.6

TABLE 1.—*Mean grain yield, 100-seed weight, and seed density of 4 sorghum genotypes treated with foliar rust fungicides (0.5 kg/ha triadimefon at boot stage and 1.0 kg/ha oxycarboxin 2 weeks later) or not treated under semi-arid conditions in southwest Puerto Rico, Lajas, summer 1986*

Sorghum genotype	Fungicide treatment	Grain yield (1,000 kg/ha)	100-seed weight	Seed density
			g	g/cm³
FS25A	+	3,230	2.1	.83
Hybrid	–	2,493	1.7	.81
Haygrazer	+	2,493	1.6	.73
Hybrid	–	2,100	1.2	.67
TAM428	+	3,694	2.3	.81
Inbred	–	3,570	2.4	.85
SC307	+	2,475	2.0	.82
Inbred	–	1,511	1.1	.80
Effects[1]				
	Genotype (G)	**	**	NS
	Fungicide (F)	**	**	NS
	G X F	**	**	NS

[1]Significance of F values from analysis of variance; ** = statistically significance at P = 0.01 and NS no statistical significance at P = 0.05.

TABLE 2.—*Percentage of losses from sorghum rust in 3 genotypes from fungicide responses under semi-arid conditions in Lajas, Puerto Rico during the summer of 1986*

Sorghum genotype[1]	*Yield loss (%)*	*100-seed weight loss (%)*
FS25A Hybrid	22.8[2]	19.0
Haygrazer	15.8	25.0
SC307	38.9	45.0

[1]TAM428 inbred grain sorghum was not included because no rust losses were detected in this genotype.

[2]Percentage loss ={(Fungicide Treatment Value - Nontreated Control Value)/Fungicide Treatment Value) (100)}. Fungicide treatment consisted of one application of 0.5 kg/ha triadimefon at boot stage followed by 1.0 kg/ha oxycarboxin 2 weeks thereafter.

g). Seed density showed no statistically significant differences among treatments, genotypes, or the interaction of those factors.

Disease Assessment

Rust coverage without fungicide treatment was 1.1, 9.3, 16.0, and 16.0% for TAM428, Haygrazer, SC307, and FS25A, respectively (table 3). Fungicide treatment reduced rust by over 90% in TAM428 and approximately by 60 to 80% in the other genotypes. A moderate degree of grey leafspot was noted and it showed some reduction in all cultivars with fungicide treatment. Genotypes varied widely in the percentages of functioning leaves present at PM (table 3). TAM428 had approximately 80% functioning foliage compared to 10% for SC307. Fungicide treatment significantly ($P = 0.01$) increased foliage viability in all cultivars except TAM428.

DISCUSSION

In past tests under sub-humid conditions in Puerto Rico, rust fungicide stimulated yield of SC 307 grain sorghum by 20 to 30% (7, 8). In this test under semi-arid conditions, 38.9% greater yield was found after fungicide application in the same genotype.

Ninety percent foliar necrosis at physiological maturity (PM) was noted for SC 307 in this study. This extreme premature folilar necrosis was not noted in earlier studies under more humid conditions.

In the semi-arid environment, periodic drought stress was observed. Drought stress was associated with a 1,000 to 1,500 kg/ha less yield in TAM 428, which does not respond to rust control. Soil fertility and sunlight were greater in this semi-arid test and pest and disease problems less severe than in past analysis under sub-humid conditions; in this way, the overriding effect of water stress can be seen in determining the yield level.

TABLE 3.—*Sorghum (*Sorghum bicolor *(L.) Moench.) rust (*Puccinia purpurea *(Cooke) and grey leafspot (*Cercospora sorghi *El. & Ev.) ratings and percentage of functional green viable leaf area at physiological maturity in 4 genotypes either fungicide treated (0.5 triadimefon at boot stage and 1.0 kg/ha oxycarboxin 14 days later) or not treated under semi-arid condition in Lajas, Puerto Rico, mid-September 1986*

Sorghum Genotype	Fungicide treatment	(%) Leaf rust Cover[1]	Sat.[2]	Grey Leafspot[3]	Viable leaves
					%
FS25A	–	16.0	64.0	3.0	60
Hybrid	+	3.0	12.0	1.5	80
Haybrazer	–	9.3	37.2	3.0	20
Hybrid	+	1.9	7.6	1.5	67
SC307	–	16.0	64.0	3.0	10
Inbred	+	6.7	26.8	1.5	50
TAM428	–	1.1	4.4	2.0	78
Inbred	+	0.1	0.4	1.5	84
Effects[4]					
	Genotype (G)	**	**	NS	**
	Fungicide (F)	**	**	*	**
	G X F	**	**	NS	*

[1]Leaf coverage by sorghum rust rated with modified Petersen scale at physiological maturity.

[2]Rust saturation percentage based on maximum rust covers 25% of total real leaf area.

[3]Grey leafspot rating at physiological maturity using Fredericksen's 5-point scale.

[4]Statistical significance of F values based on analysis of variance; ** = significance at P = 0.01, * = significance at P = 0.05, and NS = not statistically significant at P = 0.05.

The association of drought stress with increased rust losses in SC307 suggests that rust and drought may act synergistically to reduce plant performance. Rust pustules greatly increase plant evaporation by the rupturing of the cuticle during their emergence (4, 5, 15). Stomate transpiration is reduced by rust infection (4, 5, 15). However, during the night when stomata are closed, rust infected plants with pustules lose 4 times as much water as healthy plants. Water losses in rust-infected plants may be especially critical when marginal supplies of water are available. Marked defoliation observed in this study is most likely caused by synergistic damage from drought and rust.

Hybrid Responses

Forage sorghum hybrids showed significant losses from sorghum rust (approximately 16 to 23%), but not to the same degree as SC307 dwarf grain sorghum (approximately 39%). Since rust pustule density and size are similar in both FS25A and SC307, yield losses might be expected from comparable levels. However, yield losses were about 40% less in FS25A than in SC307 (table 2). Furthermore, about 6 times more functioning leaf area was present in FS25A at PM than in SC307 (table 2). Furthermore, about 6 times more functioning leaf area was present in FS25A at PM than in SC307 when rust was not controlled chemically (table 3). FS25A appears to show more tolerance to rust than SC307. This tolerance may be conditioned by better drought tolerance, hybrid vigor, or height differences between FS25A and SC307. Niehaus and Pickett (13) assert that both hybrid and tall genotypes generally perform better in terms of growth and yield. Height and heterosis, although often associated, are not synonymous.

Increased height of hybrids can lead to overestimation of hybrid vigor when taller hybrids are compared with dwarf parents.

Haygrazer, showing reduced rust coverage and pustule size, is more resistant than SC307. However, viable leaf tissue at physiological maturity was similar to that of SC307 when neither was treated with rust fungicide. Moreover, the viable leaf after fungicide treatment of both genotypes increased similarly. Nevertheless, yield loss in Haygrazer (approximately 16%) was much lower than that of SC307 (approximately 39%). This finding suggests Haygrazer has greater tolerance to defoliation than SC307.

Besides the greater tolerance of Haygrazer to defoliation and greater tolerance of FS25A to rust severity than SC307, both Haygrazer and FS25A showed greater rust reductions after fungicide treatment than SC307. Better response to rust control, greater yield maintenance at similar levels of defoliation, and greater percentage of functioning leaves at similar levels of rust may be ways hybrids and tall varieties show their physiological superiority to dwarf inbred genotypes.

A notable physiological difference between inbreds and hybrids is expressed by the greater vigor and stress tolerance of hybrids. Compared to dwarf varieties, tall sorghums have greater concentration of gibberillins, which may aid in growth and contribute to their tolerance to environmental stresses. Further information on the effects of height on disease reactions can be provided in comparisons of isogenic lines varying only in the number and type of their dwarfing genes.

CONCLUSIONS

Losses from sorghum rust are not restricted to subhumid tropical zones or to sorghum inbreds. These losses extend to tropical semiarid zones and include hybrid sorghums. Under semiarid conditions, foliar necrosis at maturity and yield losses in SC307 were higher than those found under more humid conditions. In this environment, more frequent drought stress appears to combine with rust to greatly increase plant losses. Despite the high rust rating and low viable foliage at physiological maturity of FS25A and Haygrazer hybrid sorghum, yield losses were less than in SC307 dwarf grain sorghum. Furthermore, fungicide treatment was more effective in reducing rust severity in the hybrids than in SC307. Sorghum hybrid vigor and tallness correlated well with the rust tolerance observed. Greater study of rust tolerance mechanisms is needed.

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