Sorghum rust: II. Control and losses[1]

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ABSTRACT

Four sorghum lines of varying rust susceptibility, ranging from very resistant to susceptible, were planted in early September 1985 in Isabela, Puerto Rico. Rust reactions were periodically evaluated from boot stage until grain harvest. At physiological maturity, foliar rust coverage was 24, 19, 7, and 0.5% for SC 212, SC 307, TAM 428, and SC 120, respectively. Four rust fungicide (oxycarboxin at 0.5 kg/ha/spray), applications at and after boot stage resulted in final rust coverage of 7, 3, 1, and 0% on SC 212, SC 307, TAM 428, and SC 120, respectively. Over all cultivars, one, two, and four applications gave 32.9, 73.7, and 85.4% rust control compared to the nontreated plots. In moderately and very resistant varieties (TAM 428 and SC 120), rust control was greater (74.5%) than that found in moderately and very susceptible ones (55.2% for SC 307 and SC 212). On SC 307 and SC 212, yield losses from rust were 29 and 50%, respectively. Reductions in 100-seed weights in SC 307 and SC 212 (28 and 41%, respectively) approximated yield loss levels. Yield of SC 212 was superior to that of SC 307 when rust was controlled with oxycarboxin and inferior to that of SX 307 when rust was untreated. Moderately rust resistant TAM 428 showed no response to rust control despite 7% rust coverage. This same rust level reduced yield of the susceptible varieties. Because of the genotypic differences in rust-yield reactions, a generalized model relating visual rust coverage to plant performance appears inappropriate.

RESUMEN

La roya del sorgo: II. Combate y pérdidas

En septiembre de 1985, se probaron líneas de sorgo que presentaron diferentes grados de susceptibilidad a la roya en Isabela, Puerto Rico. Durante la etapa de madurez fisiológica los porcentajes de área foliar afectada por la roya fueron 24, 19, 7 y 5 en las variedades SC 212, SC 307, TAM 428, y SC 120, respectivamente. Cuatro aplicaciones foliares de oxicarboxin (0.5 kg./ha.) durante la etapa de la hoja bandera y después de ella reprimieron la roya hasta obtenerse valores finales en porcentaje del área foliar afectada de 7, 3, 1 y 0, respectivamente, en las mismas variedades. Una, dos y cuatro aplicaciones reprimieron la roya en un 32.9, 73.7, y 85.4%, respectivamente, en estas cultivares. La eficacia de la represión química del patógeno fue mayor en variedades con alta o moderada resistencia a la roya (74.5%) si la comparamos con las variedades de moderada resistencia o de alta susceptibilidad (55.2%). La enfermedad redujo los rendimientos en 50 y 29% en las cultivares SC 212 y SC 307, respectivamente. Las respuestas en rendimiento al reprimir la roya fueron mayores en la variedad SC 212 que en la SC 307. El peso de 100 semillas disminuyó 41% y 28% en SC 212 y SC 307, respectivamente.

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INTRODUCTION

Rust caused by *Puccinia purpurea* Cooke has been considered a minor disease of sorghum (*Sorghum bicolor* (L.) Moench. (4,6,7,11). On cereal crops, rust causes sizable economic losses (5). There is little information on the effects of rust on sorghum production. In Hawaii, rust was suspected of lowering sorghum yields (1). In Puerto Rico, Hepperly (2) found 20 to 40% grain increase in rust susceptible sorghum varieties which were treated with rust specific fungicides. Use of isogenetic lines varying only in rust resistance genes is an alternative method for determining rust losses. These lines, however, are not presently available and are costly to produce. Furthermore, in developing rust resistant sorghum populations about half of the identified sources of rust resistance do not show stable rust reactions (Hepperly, unpublished).

Given the potential importance of sorghum rust, further rust loss studies are needed and incorporation of increased rust resistance into sorghum germplasm is warranted. Rust resistance breeding can be complicated by races of the pathogen that might overcome host resistance genes (8, 10). Because of the expensive and time consuming nature of disease resistance breeding, disease losses should be thoroughly verified before resistance breeding programs are initiated.

The following study was conducted to corroborate sorghum rust loss estimates and to determine the frequency of oxycarboxin applications required to control sorghum rust in northwest Puerto Rico.

MATERIALS AND METHODS

A split randomized complete block design was used. Main plots were either 0, 1, 2, or 4 applications of oxycarboxin (Plantvax 75W).[3] Oxycarboxin, which is produced by Uniroyal Chemical Company, has highly specific toxicity toward basidiomycetes and moves systemically in the xylem of herbaceous plants. Subplots were 4 sorghum cultivars (SC 212, SC 307, TAM 428, and SC 120) which are very susceptible, moderately susceptible, moderately resistant and very resistant to rust, respectively. Each experimental unit consisted of four 5-m long sorghum rows with a 1-m row spacing. Approximately 1 g of sorghum seed per m row was planted and seedlings were thinned to 12 to 15 plants per meter (120,000 to 150,000 plants per ha). The experiment was conducted during the fall of 1985 in Isabela, Puerto Rico under conditions favoring severe rust. Oxycarboxin (0.5 kg/ha) was applied using a handpump backpack sprayer (20 l Solo) at low pressure to minimize drift. Application schedule

[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 or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

was: i) one application 17 days after boot stage (DAB); ii) two applications, one at boot stage and another at 17 DAB; and iii) four applications, one at boot and 3 others at 1, 2, and 3 weeks after boot stage. Since in a previous study (2) oxycarboxin stimulated anthracnose development, all plots in this study were sprayed with benomyl, which controls anthracnose but not rust.

Rust readings were taken at boot stage and 10, 16, 21, 27, and 37 days thereafter, with a modified 5-point Petersen rust scale where severity values were converted into estimated areas of rust coverage (2). Maximum rust was estimated at 25% leaf area actually covered by pustules. Six random panicles were selected in each of the two center rows of each subplot and bagged. Panicles were harvested in early December and dried to 14% moisture under forced air at 40° C. Grain was threshed, cleaned and weighed. From each subplot, a 25-cm^3 sample volume was taken for determining seed density. From each sample, 100-seed samples were counted and weighed to estimate seed mass.

Rust control efficiency was calculated by comparing rust severity in the nontreated control (C) with that of the fungicide treatment (F). The following formula was used: $[(C - F)/C] \times 100$. In this analysis, when F = C rust control efficiency is 0, and when F = 0 and C is positive, 100% efficiency results. Yield responses from rust control are determined with the following formula: $[(F - C)/C] \times 100$. When fungicide treatment yields exceed the control, responses are positive and when nontreated yield exceeds the fungicide treatment, values are negative.

Data were analyzed for variance and means separated using Fischer's Least Significant Difference ($P = 0.05$). Fungicide spray frequency was related to rust development and yield using linear regression analysis.

RESULTS

Over 60 and 80% rust control was found on SC 212 and SC 307, respectively (table 1). In these susceptible lines, two intervals of rapid rust increase were identified. These were from boot stage to 10 days thereafter and from 21 to 27 DAB (fig. 1).

Variable levels of host resistance and frequencies of chemical control resulted in an array of rust severities. In sorghum lines with moderate resistance to rust, chemical control of rust was greater than that found in susceptible lines (table 1). However, no yield response was detected in rust resistant lines when rust was controlled. Yield response increased as sorghum susceptibility increased. Yield increased by 29 and 50% in moderately and very susceptible lines, respectively, when fungicide treatment was optimum (table 1).

In the susceptible varieties, SC 212 and SC 307, losses in seed mass (100-seed weight) were similar to losses in yield. In the very susceptible SC 212 rust control increased seed density (table 1). SC 312 outyielded

TABLE 1.—*Sorghum rust control, yields, 100-seed weights and seed densities in four sorghum lines of variable rust reactions under four regimes of chemical rust control in Isabela, Puerto Rico in the fall of 1985*

Cultivar[1]	Spray number[2]	Percent rust control	Grain yield	100-seed weight	Seed density
			kg/ha	*g*	*g/25 cm³*
SC 212	0	0.0	1,085	1.3	15.6
	1	16.7	1,088	1.5	16.9
	2	50.0	1,588	1.8	16.4
	4	70.8	2,173	2.2	19.4
SC 307	0	0.0	1,383	2.3	21.1
	1	35.0	1,563	2.5	21.9
	2	65.0	1,780	2.8	21.3
	4	85.0	1,953	3.2	21.1
TAM 428	0	0.0	5,175	2.9	20.4
	1	0.0	4,838	2.7	20.1
	2	71.4	5,810	2.8	20.9
	4	85.7	4,738	3.0	20.6
SC 120	0	0.0	2,938	2.9	18.9
	1	80.0	2,980	3.1	19.0
	2	100.0	3,230	3.3	19.0
	4	100.0	2,913	3.2	19.3

[1] Within each variety statistically significant differences among treatments (spray regimens) were found for rust control; SC 212 and SC 304 showed treatment differences in grain yield and 100-seed weights; and SC 212 showed treatment differences in seed density according to Fischer's Least Significant Difference (FLSD) at P = 0.05.

[2] Sprays with oxycarboxin (0.5 kg a.i./ha). One application at 17 days after boot (DAB); two at boot and 17 DAB; and four sprays at boot and 1, 2, and 3 weeks thereafter.

SC 307 when rust was controlled and yielded less than SC 307 without rust treatment (table 1).

Spray frequency was inversely related to rust development in rust susceptible lines but not in resistant ones (table 2). Relative susceptibility of the susceptible lines used was reflected by differences in y-intercepts and slope values in the spray-rust regression analysis.

DISCUSSION

In this study, 30 to 50% yield losses were found in susceptible sorghum lines; in comparison, 20 to 40% losses were found in the same lines at the same site in a previous study (2). Rust control, in the present study, was enhanced compared to the previous one by increasing the number of rust sprays from 2 to 4. Furthermore, by applying benomyl to all plots late season anthracnose epidemics, which were stimulated by oxycarboxin in the first study, were greatly reduced in severity in this study. Elimination of the secondary effect of increased anthracnose and more efficient

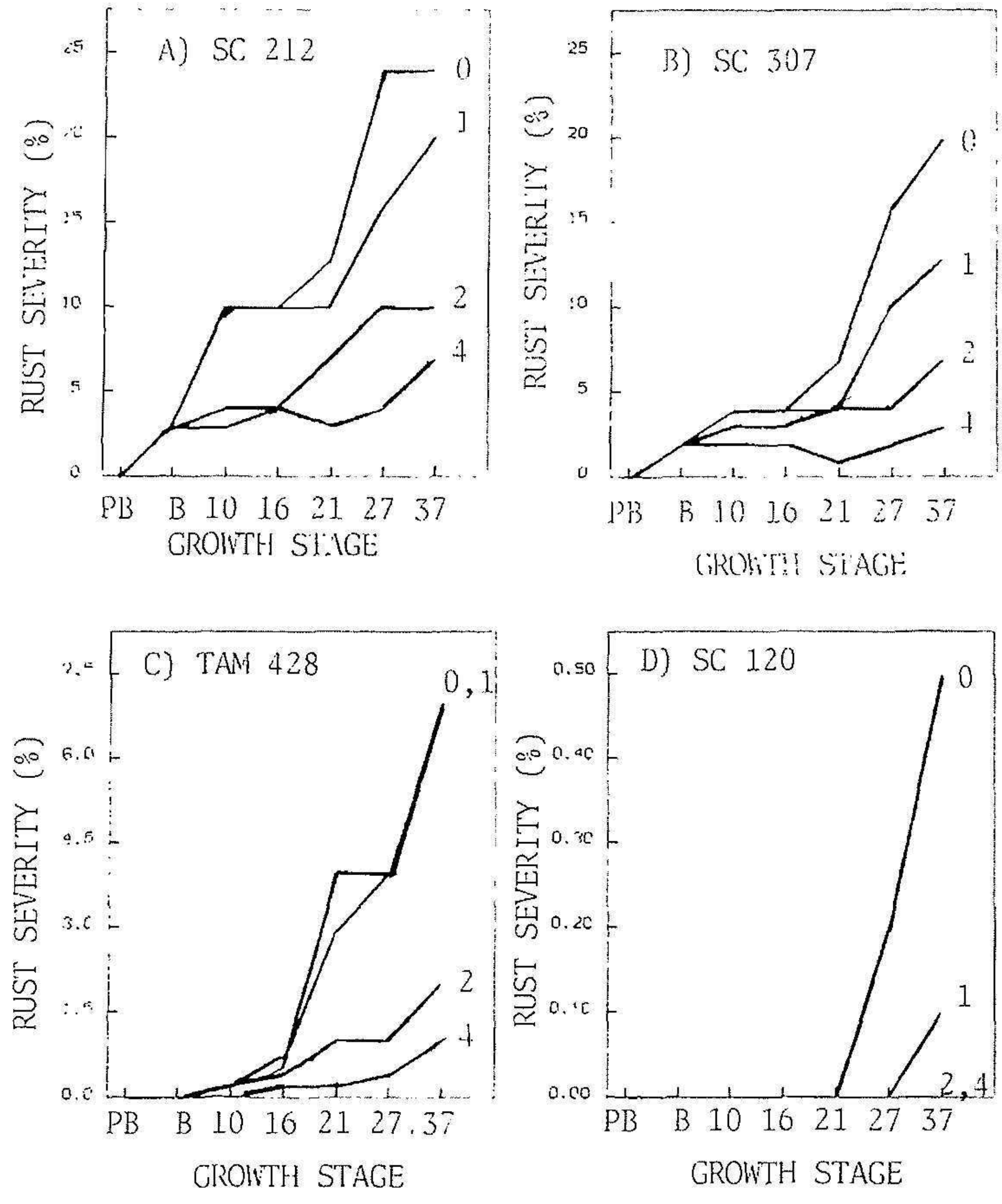

FIG. 1.—Sorghum, *Sorghum bicolor* (L.) Moench. rust *Puccinia purpurea* Cooke severity (% foliar coverage by pustules) in pre-boot (PB), boot stage (B), and 10, 16, 21, 27, and 37 days after boot stage under 0, 1, 2 or 4 applications of 0.5 kg a.i./ha. oxycarboxin, and D) SC 120 sorghum cultivars which are very susceptible, moderately susceptible, moderately resistant and very resistant to sorghum rust, respectively.

rust control by increased applications led to better estimation of real rust losses.

A big problem in using fungicides for estimating disease losses is the nontarget actions of these treatments. When researchers are on the lookout for side effects, these can be identified and corrected. The non-

TABLE 2.—*Relationships of sorghum rust severity and spray number to sorghum grain yield and the interrelationships of the two first mentioned variables from experiments with rust susceptible sorghum lines under a fall rust epidemic in Isabela, Puerto Rico in 1985. Either 0, 1, 2, or 4 applications of oxycarboxin rust fungicide were used to partially control rust*

Variables	Sorghum line[1]	Linear[2] correlation coefficient (r)	Slope	Y-intercept
Rust severity (y) vs	SC 212	−0.94 *	−4.4	23.0
Spray number (x)	SC 307	−0.95 *	−4.1	18.0
Grain yield (y) vs	SC 212	−0.92 *	−58.8	2,371
Rust severity (x)	SC 307	−0.99 ***	−33.4	2,028
Grain yield (y) vs	SC 212	+0.97 **	293.0	963.2
Spray number (x)	SC 307	+0.98 **	142.5	1,420.4

[1]TAM 428 and SC 120 showed no significant relationships between rust and yield, and are not presented.

[2]Linear correlation coefficient (r) significance denoted at * = P 0.05, ** = P 0.01, and *** = P 0.001, respectively.

target effect of rust specific fungicide in stimulating anthracnose was identified because data on anthracnose was taken along with rust readings. Before experiments are performed, side effects cannot be foreseen. Scientific vigilance and flexibility are the only safeguards against losing information about important unforeseen events. Over emphasis on a preconceived hypothesis and performance of experiments by support staff can handicap scientific observation and limit experimental insights.

In moderately and very susceptible varieties with optimum rust control (4 sprays), rust was reduced by 85% and 70%, respectively. Since complete rust control was not obtained and susceptible varieties continued to show yield response between 2 and 4 applications, it is probable that current loss estimates continue to underestimate real rust losses on susceptible lines.

Without fungicide treatment, rust epidemics on susceptible lines showed two peaks of disease severity increase, i.e. from boot stage to 10 DAB, and from 21 to 27 DAB. In TAM 428 and in fungicide treated plots of the susceptible varieties, high rates of rust increase were noted from 27 to 37 DAB. On the other hand, during the same period in nonsprayed susceptible lines rust increase rates were decreasing. This can be explained if noninfected tissue available for infection becomes a limiting factor in susceptible varieties. High rates of rust increase from 27 to 37 DAB on TAM 428 and sprayed susceptible varieties suggest environmental conditions during the period were favorable to rust development provided infection sites were available.

Sorghum yield losses from rust correlate well with 100-seed weight reductions. Sorghum rust causes reductions in yield by lowering in per seed mass while not affecting seed numbers. When rust was not controlled in SC 212, the most susceptible variety to rust, lower seed density was detected. Seed vigor often correlates with seed density (3). Future workers should examine the relation of sorghum rust to seed vigor.

Berquist (1) believed that rust caused important losses in sorghum in Hawaii. This study and a previous one in Puerto Rico (2) corroborate his observation. Apparently, Hawaii and Puerto Rico share similar tropical oceanic climates which are favorable to severe sorghum rust. Under these conditions, rust control measures are essential for optimizing sorghum yield and quality.

The rust effect in traditional sorghum production zones is less clear. Perhaps these semiarid temperate zones do not favor rust or rust arrives very late in the season. Alternatively, rust losses in these zones may be inadequately diagnosed because of insufficient experimentation and inadequate methodology. Where rust is common and believed of minor consequence, use of specific rust fungicides and control of rates, timing, and nontarget actions might be needed to obtain reliable data. To my knowledge these studies have not been done in a semi-arid temperate zone. Development of near isogenetic populations varying in rust resistance would be helpful in testing the effects of rust in the long term. All approaches to disease loss assessments demand careful attention to disease interactions which can confound well intentioned experimentation.

Diseases, such as rust and powdery mildew, affect seed indirectly. These usually act by reducing photosynthesis and by diverting leaf energy to pathogen biomass rather than to seed. The pathogens rarely infect the seed per se, but like the seed, the pathogen becomes an energy sink. As an energy sink they compete directly with developing seeds. Since all field plants in commercial monocultures can become infected with this type of pathogen, noninfected plants are not available naturally for comparison of yield and quality. Judging rust impact without experimentation data is common in literature accounts. Nonetheless, only well planned experimentation can accurately analyze the potential of rust to reduce yield and quality.

TAM 428 showed up to 7% rust coverage (25% rust saturation) without effect on yield or quality. At these same levels of rust, SC 212 and SC 307 showed positive response to rust control measures. Among the susceptible varieties, rust control response was not parallel. Considering the highly individualistic responses of sorghum varieties in terms of rust control response, a valid model relating loss to rust severity could not be generalized over genotypes.

Sorghum rust losses in Puerto Rico (2) were corroborated. These substantial losses are controllable chemically and by host resistance. Although chemicals are excellent research tools for determining rust losses, they were not economically viable for commercial production from this data. Chemical control might be profitable if yield potential of the susceptible lines were greater and sorghum prices higher.

Resistance should be preferred to chemical control not only for an economic advantage but also because nontarget effects of pesticides on fauna and flora can be reduced and residues in harvests avoided (9). Increased sorghum rust resistance is a viable method of improving sorghum performance in rust conducive environments.

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