Influence of Nonhost Summer Crops on Take-all in Double-Cropped Winter Wheat

CRAIG S. ROTHROCK, Department of Plant Pathology, University of Georgia, Georgia Station, Griffin 30223, and G. W. LANGDALE, USDA-ARS, Southern Piedmont Conservation Research Center, Watkinsville 30677

ABSTRACT

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Sorghum and soybean were grown as summer crops in double-cropping systems with winter wheat on southern Piedmont soils. Wheat following sorghum had significantly less take-all than wheat following soybean over three growing seasons at two sites. Site one had no history of take-all and site two had a history of severe take-all. Sorghum also reduced take-all on wheat when grown as the summer crop in 2 of the last 3 yr compared with a continuous soybean summer crop at site one. Wheat yields at both sites were significantly ($P = 0.05$) greater following sorghum than following soybean. Wheat yields also were negatively correlated ($P = 0.0001$) with take-all damage in both studies.

Additional keywords: crop rotation, *Gaeumannomyces graminis* var. *tritici*, *Glycine max*, *Sorghum bicolor*, *Triticum aestivum*

Crop rotation is one of the most effective controls for take-all of wheat (*Triticum aestivum* L. em Thell), caused by *Gaeumannomyces graminis* (Sacc.) von Arx & Olivier var. *tritici* Walker (27). Control of diseases by crop rotation is usually attributed to death of the pathogen in the absence of a susceptible host as infested residue decomposes (7). However, nonhost crops also may play an important role in disease control by crop rotation. Cook (5) reported that take-all was common following a 3-yr bean (*Phaseolus vulgaris* L.)/soybean (*Glycine max* (L.) Merr.) rotation but was mild or nonexistent following potato (*Solanum tuberosum* L.), oats (*Avena sativa* L.), and alfalfa (*Medicago sativa* L.). Huber (15) observed that winter wheat in Indiana was more severely diseased following a summer soybean crop than following corn. Other reports also suggest legumes perpetuate the survival of the pathogen, including alfalfa in the United States (6) and South Africa (19) and subterranean clover (*Trifolium subterraneum* L.) in Australia (26). The role of graminaceous weeds in carryover of inoculum in these situations was unclear. In contrast, Prew and Dyke (21) found that oats, clover, broadbean (*Vicia faba* L.), and corn (*Zea mays* L.) were equally effective in reducing take-all in winter wheat. Kollmorgen et al (17) also found that lupin (*Lupinus angustifolius* L.), medic (*Medicago* spp.), and pea (*Pisum sativum* L.) were as effective as fallow in reducing disease in the subsequent small grain. Little research has been done on the influence of nonhost crops on take-all in multiple-cropping systems. In Georgia, soybean did not influence take-all in a wheat/soybean double-cropping system compared with summer fallow in the initial stages of wheat monoculture (22).

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Wheat is frequently grown in double-cropping systems with a summer crop in the southeastern United States because of favorable rainfall and temperature patterns. In addition to its economic value, wheat is an important component along with conservation tillage in reducing soil erosion. Soybean is the most common summer crop (14), although other summer crops, including sorghum (*Sorghum bicolor* (L.) Moench), will fit into double-cropping systems with wheat. In this cropping system, winter wheat is produced annually, similar to wheat monoculture. A summer crop, however, is planted after wheat harvest in June and harvested before wheat planting in November. This cropping system allows the opportunity to examine how different crops influence survival of *G. g.* var. *tritici* and take-all development in the subsequent wheat crop in a system where wheat is grown annually.

This research compared the influence of two nonhost summer crops on take-all of winter wheat in a double-cropping system at a site with no history of take-all and a site with a history of severe take-all.

MATERIALS AND METHODS

Experimental sites. Plots were established on a site at Watkinsville, GA, that had been in wheat and soybean prior to the study. The soil was a Cecil sandy loam (clayey, kaolinitic, thermic, Typic Hapludults) with an average pH of 6.0. The experiment was a split-split plot design with three replications (18). Each experimental unit was 3.0 × 9.1 m. The main plots were the tillage treatments conventional (offset disk harrow), minimal (in-row chisel), and no tillage before planting the summer crop. Subplots were 10 different 4-yr wheat/soybean or wheat/sorghum rotation sequences. The 4-yr summer rotation frequencies were continuous soybean (s), continuous grain sorghum (gs), s-gs-s-gs, s-s-gs-s, s-s-s-gs, s-s-gs-gs, gs-gs-s-s, gs-gs-gs-s, gs-gs-s-gs, and gs-s-gs-s. There were 18 experimental units for each rotation sequence. High and low herbicide treatments for the summer crop were the sub-subplots. The study was initiated in the fall of 1979 and continued for two 4-yr rotation cycles. Wheat was planted after disking in mid-November each year with the cultivar Stacy. The center 1.5 × 9.1 m of the experimental units were harvested with a small plot combine. Yields were adjusted to 13.0% moisture. All crop residues were returned to plots after harvest.

The site at Griffin was double-cropped between 1978 and 1982 with wheat and soybean and was in wheat monoculture between 1983 and 1985. The soil also was a Cecil sandy loam with an average pH of 5.8. The site at Griffin was part of a take-all rotation experiment that was a strip-split plot design with three replications. The main plot consisted of the time prior to planting the entire main plot in wheat: 1, 2, or 3 yr. Subplots were the winter crop treatments: wheat, oats, and fallow. The summer crop treatments—soybean, fallow, and sorghum—were stripped across the winter crop treatments. The soybean summer crop was the only summer crop treatment included in the 3-yr main plots. Experimental units were 2.1 × 4.6 m. Only experimental units having an annual wheat crop were used in the analyses. All crops were planted without tillage to minimize spread of infested residue. Fertilizer rates for wheat were 30 kg/ha of P and 37 kg/ha of K at planting and 67 kg/ha of N in the spring. The summer fallow plots also received 22 kg/ha of N, and the sorghum plots 34 kg/ha of N, before wheat was planted in the fall. Fertilizer rates for sorghum were 100 kg/ha of N, 67 kg/ha of P, and 90 kg/ha of K. Fertilizer rates for soybean were 34 kg/ha of P and 77 kg/ha of K. The wheat cultivar Stacy was planted on 16 November 1985, 1986, and 1987. During the 1987 and 1988 growing seasons, three random 1-m lengths of row were counted for tillers at decimal growth stages 83 (28) for each experimental unit. The center 1.5 × 3.3 m of the plots were harvested with a small plot combine in 1986 and the center 1.0 × 3.0 m were harvested by hand in 1987 and 1988. Yields were adjusted to 13.0% moisture. The summer crops were planted in late June after the winter crops were harvested. Weeds in the summer crops were controlled with metolachlor (2.2 kg a.i./ha) and paraquat (0.4 kg a.i./ha). Hand weeding was done as required. Crop residues were returned to plots after harvest.

Disease assessment. Take-all was assessed in the 1985, 1986, and 1987 growing seasons at Watkinsville. Whitehead estimates were based on the number of meters of row with whiteheads divided by the total number of meters of row per plot. When there was a question of whether whiteheads were due to take-all, the root systems of the plants were examined for symptoms of take-all. In 1987, a total of 20 primary tillers were collected randomly in rows 2, 3, 14, and 15 from the 16 rows in each experimental unit with summer cropping histories of continuous sorghum or continuous soybean. All whitehead and tiller samples were made at decimal growth stage 83. Samples were washed and examined under a dissecting microscope for black discoloration of the stele, a symptom characteristic for take-all. Disease severity was assessed as the proportion of diseased roots. The scale was 0 = no symptoms, 1 = lesions on <25% of the roots, 2 = lesions on 25 to <50% of the roots, 3 = lesions on 50 to <75% of the roots, and 4 = lesions on 75–100% of the roots (24). The weighted mean disease severity was calculated by multiplying the number of root systems in each of the five severity categories by the value of that category and dividing the sum by the total number of tillers examined.

Plots were randomly sampled from all rows except the outside rows from the rotation study at Griffin. Ten primary tillers per experimental unit were collected in 1986 and 15 in 1987 and 1988. Disease assessment for tiller samples was the same as for Watkinsville samples.

Statistical analyses. Data were analyzed by the appropriate experimental design using SAS (SAS Institute, Cary, NC). For analyses over several years, year was considered as the main plot. No significant interactions between the main effects were found, so the analyses of the main effects were appropriate. Following a significant *F* test, a least significant difference (LSD) test was performed. The Pearson product-moment correlation method was used to determine correlation coefficients between yield and take-all rating.

RESULTS

Take-all was first observed as whitehead symptoms in plots at Watkinsville in 1984. Take-all severity, as judged by whitehead symptoms, was not significantly different during the 1985, 1986, and 1987 growing seasons. Take-all averaged 7.0% whiteheads over all treatments during the study. The study at Griffin was established on land with a history of take-all and wheat production. In 1985, the year before the study was initiated, wheat had a mean root disease severity rating of 3.9 (Rothrock, *unpublished*). Disease severity at Griffin was significantly lower (av. 1.8) in 1986 than in 1987 and 1988 (av. 2.8).

Summer cropping history had a significant influence on take-all at Watkinsville (Table 1). The other main effects—summer tillage treatment and summer herbicide level—did not have a significant influence on take-all. Plots having 3 yr of soybean had significantly more whiteheads than plots having 3 yr of sorghum. Plots with sorghum in 2 of the last 3 yr were not significantly different from 3 yr of sorghum but were different from 3 yr of soybean. This difference in take-all severity, indicated by the whitehead data, among summer crop rotations was confirmed by root disease data for the two continuous summer cropping systems. Wheat following a continuous soybean summer crop sequence had significantly greater disease incidence and severity ($P = 0.05$), with 38% of the plants having symptoms and with a disease severity of 1.1, than wheat following a continuous sorghum summer crop sequence, with 22% of the plants having symptoms and with a disease severity of 0.5.

At Griffin, wheat following a sorghum summer crop also had a significantly lower take-all severity than wheat following a soybean summer crop (Table 2). Disease severity for wheat following the summer fallow treatment was intermediate between the two summer crop treatments and was significantly lower than for wheat following soybean. Disease incidence for all rotation treatments was high and did not differ significantly among treatments.

Wheat following sorghum for the past three summers yielded significantly more than wheat following 3 yr of soybean at Watkinsville from 1985 to 1987 (Table 1). Plots with mixed summer cropping histories during the past 3 yr were generally intermediate in grain yield. At Griffin, yields were significantly greater

Table 1. Influence of summer crop rotation on take-all in double-cropped winter wheat for the 1985–1987 growing seasons at Watkinsville, GA

Past summer crops[x]	Whiteheads (%)[y]	Yield (kg/ha)
Soybean-soybean-soybean	12.6 a[z]	3,341 b
Sorghum-soybean-soybean	8.1 ab	3,172 a
Soybean-soybean-sorghum	8.1 ab	3,456 bc
Soybean-sorghum-soybean	7.8 ab	3,505 cd
Sorghum-soybean-sorghum	5.7 b	3,571 cd
Sorghum-sorghum-soybean	5.5 b	3,535 cd
Soybean-sorghum-sorghum	5.3 b	3,324 ab
Sorghum-sorghum-sorghum	2.6 b	3,624 d

[x] Last three summer crops before data were taken.
[y] Calculated from meters of row with whitehead symptoms.
[z] Means followed by the same letter in a column are not significantly different according to LSD ($P = 0.05$).

Table 2. Influence of summer crop treatment on take-all in double-cropped winter wheat for the 1986–1988 growing seasons at Griffin, GA

Summer crop treatment	Disease severity[x]	Plants infected (%)	Tillers per meter[y]	Yield (kg/ha)
Soybean	3.0 a[z]	92 a	60.9 a	1,754 a
Fallow	2.3 b	82 a	68.4 ab	2,437 b
Sorghum	1.9 b	83 a	75.0 b	2,536 b

[x] Rated on a scale of 0–4, where 0 = no roots with symptoms and 4 = 75–100% of roots with symptoms.
[y] Data from 1987 and 1988 growing seasons only.
[z] Means followed by the same letter in a column are not significantly different according to LSD ($P = 0.05$).

following sorghum than following soybean (Table 2). Wheat yields for the summer fallow treatment were also significantly greater than for wheat following soybean. This increase in growth for wheat following sorghum also was reflected by tillers per meter, which were increased over those for wheat following soybean during the 1987 and 1988 growing seasons. Yields at Griffin were significantly different among years: 2,769 kg/ha in 1986, 1,050 kg/ha in 1987, and 2,699 kg/ha in 1988. Yield was negatively correlated with take-all ratings in both studies ($P = 0.0001$). At Watkinsville, whitehead data accounted for 51% of the variation in yield over the 3 yr of data. At Griffin, root ratings accounted for 58% of the differences in yield among the experimental units over the three growing seasons.

DISCUSSION

Multiple cropping provides an opportunity to examine the influence of nonhost or rotation crops on the survival of a pathogen and disease development. This study clearly shows that nonhost crops influence disease development in the subsequent host crop. Wheat following a sorghum summer crop had significantly less take-all than wheat following a soybean summer crop. Also, this nonhost effect is present over a wide variety of disease situations, with the development of take-all being measured in the absence of an initial measurable take-all infestation at Watkinsville, whereas the Griffin site had a history of severe take-all. Thus, a summer crop can influence the buildup and subsequent maintenance or decline of the disease. The data from Watkinsville also indicate that a rotation including a proportion of sorghum can depress *G. g.* var. *tritici* as effectively as continuous sorghum. In these studies, a sorghum summer crop significantly increased wheat yields and yields were negatively correlated with take-all damage. This is in contrast to the first 4-yr rotation cycle at Watkinsville, with little or no take-all, where wheat yields were significantly lower following sorghum (18).

There are several possible mechanisms for the influence of nonhost crops on take-all of wheat (17). Nitrogen has been shown to be important in the saprophytic survival of *G. g.* var. *tritici* (2,9,10). The increase in soil fertility after legumes was reported to aid in the survival of the pathogen (3). Little is known on how different nonhost crops influence the development of take-all decline, although there is evidence that different crops may influence this microflora differently (25). Bioassays of fields in Georgia with different cropping histories suggest that soils suppressive to take-all will not develop under wheat/soybean double-cropping (23). Sorghum is reported to release numerous biologically inhibitory compounds from seedlings (20) and mature stems and roots (1,12,13) that may influence survival of the pathogen. Finally, certain nonhost crops may act as catch crops, reducing the inoculum potential of the pathogen. Sorghum (11) and corn (16) are immune to the disease. However, corn (8) as well as other plants (4) support ectotrophic growth of the fungus on roots, and the pathogen can be isolated from roots of immune plants (4,21). Thus, inoculum potential of *G. g.* var. *tritici* for the subsequent wheat crop may be lessened by unsuccessful infections of the summer crop. Data from the rotation study at Griffin indicated that take-all on wheat acted similarly following the summer fallow treatment and the sorghum treatment, suggesting that specific soil suppressiveness may be involved.

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