Relative Susceptibility of Small Grains to Take-all

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ABSTRACT

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Wheat, triticale, barley, rye, and oats were examined for relative susceptibility and performance at three infestation levels of a wheat isolate of *Gaeumannomyces graminis* var. *tritici*. All the small grains except oats were susceptible to take-all. Wheat was most susceptible. Triticale differed significantly from wheat in disease severity in only one growing season. Barley was significantly less susceptible than triticale or wheat and more susceptible than rye in both growing seasons. Cultivars within each small grain did not differ in susceptibility to take-all with the exception of Dawn barley, which had lower disease incidence and severity than the other barley cultivars tested. Take-all significantly reduced grain yield for wheat, barley, and triticale in both seasons. Wheat had the greatest yield reductions, followed by triticale and barley. Plant height, tillers per meter, and thousand kernel weight also were reduced by take-all for these three small grains. No reduction in grain yield, yield components, or plant height was found for rye. There were significant differences in reductions in yield, tillers per meter, thousand kernel weight, and plant height among cultivars of barley, triticale, and wheat.

Additional keywords: *Avena sativa, Hordeum vulgare, Secale cereale,* X *Triticosecale, Triticum aestivum*

Take-all of wheat (*Triticum aestivum* L. em Thell) has increased in importance in the southeastern United States in recent years with the increase in wheat production (14). Wheat production is almost entirely limited to double-cropping systems, in which a summer crop is produced before the annual winter wheat crop is planted (3). Control of take-all by crop rotation is difficult because few rotational crops are suited to these double-cropping systems and winter fallow may not be an economically feasible option. In addition, winter wheat is important in reducing soil erosion. This leaves the possibility of other small grains as alternative winter crops to wheat. Other small grains being produced in Georgia are barley (*Hordeum vulgare* L.), rye (*Secale cereale* L.), oats (*Avena sativa* L.), and triticale (X *Triticosecale* Wittmack). In recent years, triticale has received attention in the Southeast as a feed grain because of its high protein and lysine content.

Gaeumannomyces graminis (Sacc.) von Arx & Olivier var. *tritici* Walker is primarily a parasite of the family Gramineae (11). There is general agreement that wheat, barley, rye, and oats have decreasing susceptibility, in that order (15). There are little quantitative data, however, on the relative susceptibility and reductions in growth for these small grains as a result of take-all. Jensen and Jørgensen (5) reported the order of yield reduction by take-all for wheat, barley, rye, and oats reflected the proportion of the root system having symptoms in naturally and artificially infested field plots. Reports of the susceptibility of triticale to take-all have varied from being as susceptible as wheat to being intermediate in susceptibility between wheat and rye in field tests (2,5,16) and seedling assays (2,8,10,11).

The objectives of these field experiments were: 1) to determine the relative susceptibility of the different small grains to take-all and 2) to determine the effect of take-all on plant height, grain yield, and other yield components.

MATERIALS AND METHODS

Experimental design and plot care. The studies were conducted during the 1986 and 1987 growing seasons. The 1986 experiment was conducted at the Georgia Station (Griffin, GA) on a Davidson sandy loam (pH 6.0). The 1987 experiment was located at the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory (Byron, GA) on a Faceville sandy loam (pH 5.6). Neither site had a recent history of small grain production.

Experiments were randomized complete block split-plot designs with four replications. The experiment at Griffin had inoculum levels as the main plots and cultivars as the subplots. The small grains were randomized within the main plots. Subplot size was 1.5 × 6.1 m. The experiment at Byron had small grains as the main plot and inoculum levels as the subplots, with the cultivars of each small grain randomized within the main plots. Subplot size in 1987 was 1.5 × 5.5 m. The soil was prepared by moldboard plowing followed by disking at Griffin and by subsoiling and disking at Byron. Fertilizer rates at planting were 28, 25, and 70 kg/ha for nitrogen, phosphorus, and potassium, respectively. Prior to planting, both sites were rotavated to incorporate fertilizer and inoculum. Plots were planted on 12 and 19 November in 1985 and 1986, respectively. The experiments were topdressed with 67 kg/ha of nitrogen in the spring. The experiment at Griffin was irrigated (2.5 cm) on 18 April and 5 May 1986 because of an extended drought. Plots were harvested on 3 June 1986 and 2 June 1987 with a small plot combine.

Inoculum was grown on sterilized oat seed for 4 wk (13). The cultures were air-dried and ground using a hammer mill. The isolate of *G. g.* var. *tritici* used was isolated from wheat roots at Griffin the previous season. The fungus was reisolated from wheat roots from the experiment at Griffin in 1986 for the 1987 experiment to protect against loss in virulence. Ground oat inoculum of the pathogen was uniformly spread over plots to be infested and rotavated into the top 10 cm of soil. Infestation levels were categorized as none (no inoculum), low (1.8 g/m^2), and high (3.6 g/m^2).

At least two cultivars of each small grain were planted in each growing season. The triticale cultivar Wytch was replaced with Florico because of unavailability of seed in 1987, and the wheat cultivars Twain and Lincoln were replaced with Florida 301 and Florida 302 in 1987. Recommended seeding rates were followed for each small grain: 108 kg/ha for wheat, barley, and triticale; 80 kg/ha for rye; and 73 kg/ha for oats.

Measurement of plant growth and disease. Fifteen plants were randomly dug from all but the outside rows of each plot at Zadoks's growth stage (GS) 83 (19), and the primary tillers were stored at 2 C. Root systems were washed and examined in water against a white background with a dissecting microscope (7×) for symptoms of take-all (black discoloration of the stele of roots). For each root system the presence or absence of symptoms (disease incidence) and the percentage of the roots with symptoms were recorded. The 0–4 disease rating scale of Shipton (17) was used. A 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 root systems. Roots of selected root

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systems were plated on the selective medium of Juhnke et al (7) to confirm the presence of *G. g.* var. *tritici*. Grain yield was adjusted to 13.0% moisture. Thousand kernel weight (TKW) was calculated by weighing 200 seed per plot. Tillers were counted in three random 1-m row lengths per plot. Plant height was the mean of six random measurements per plot. Tiller counts and height measurements were recorded at GS 83.

Statistics. Data were analyzed by the general linear model procedure using the appropriate experimental design with SAS (SAS Institute, Cary, NC). Following a significant F test, a least significant difference (LSD) analysis was performed. Each experiment was analyzed by small grain or cultivars within each small grain. For comparisons among small grains or cultivars within a small grain for plant height, TKW, tillers per meter, and grain yield, relative reductions in these variables were calculated on the basis of measurements from the noninfested plots. When comparisons were made in disease severity or incidence among small grains or cultivars within a small grain, only infested treatments were included. Because no significant interactions between inoculum and cultivars or small grains were found except where noted, analyses on the main effects were sufficient and complete.

Table 1. Influence of infestation level on severity and incidence of take-all on wheat, triticale, barley, rye, and oats

		1986		1987	
Small grain	**Inoculum level**[x]	**Disease severity index**[y]	**Disease incidence (%)**	**Disease severity index**	**Disease incidence (%)**
Wheat	None	0.0 a[z]	2 a	0.1 a	8 a
	Low	3.1 b	92 b	3.7 b	100 b
	High	3.8 c	100 c	3.8 b	99 b
Triticale	None	0.0 a	0 a	0.0 a	2 a
	Low	2.2 b	79 b	3.5 b	100 b
	High	3.3 c	96 c	3.6 b	100 b
Barley	None	0.0 a	3 a	0.0 a	1 a
	Low	1.0 b	54 b	2.1 b	87 b
	High	1.6 c	79 c	2.8 c	96 c
Rye	None	0.0 a	0 a	0.0 a	2 a
	Low	0.3 a	28 b	1.3 b	68 b
	High	1.4 b	70 c	1.4 b	71 b
Oats	None	0.0 a	1 a	0.0 a	1 a
	Low	0.0 a	1 a	0.0 a	1 a
	High	0.0 a	0 a	0.0 a	1 a

[x] Low = 1.8 g/m^2, high = 3.6 g/m^2.
[y] Disease rating scale of 0–4, where 0 = no roots with symptoms and 4 = 75–100% of roots with symptoms.
[z] Means within a small grain and column followed by the same letter are not significantly different using LSD ($P = 0.05$).

Table 2. Influence of infestation level of *Gaeumannomyces graminis* var. *tritici* on grain yield, plant height, tillers per meter, and thousand kernel weight (TKW) of wheat, triticale, barley, rye, and oats

		1986				1987			
Small grain	**Inoculum level**[y]	**Grain yield (kg/ha)**	**Plant height (m)**	**Tillers/m**	**TKW**	**Grain yield (kg/ha)**	**Plant height (m)**	**Tillers/m**	**TKW**
Wheat	None	2,997 a[z]	0.77 a	92 a	35.0 a	4,326 a	1.10 a	90 a	30.6 a
	Low	1,809 b	0.63 b	58 b	31.3 b	1,170 b	0.85 b	45 b	22.7 b
	High	788 c	0.54 b	40 c	27.0 c	1,010 b	0.81 b	46 b	22.3 b
Triticale	None	3,618 a	1.01 a	57 a	43.4 a	3,919 a	1.35 a	58 a	33.0 a
	Low	2,923 a	0.94 a	48 ab	41.2 a	1,822 b	1.18 b	44 b	29.7 ab
	High	1,711 b	0.87 a	41 b	37.7 b	1,343 b	1.11 c	38 b	27.2 b
Barley	None	2,885 a	0.75 a	73 a	35.0 a	4,688 a	1.00 a	82 a	34.1 a
	Low	2,561 ab	0.71 a	62 a	32.8 b	2,582 b	0.85 b	66 ab	30.1 b
	High	2,244 b	0.72 a	60 a	30.7 c	2,244 b	0.80 b	59 b	27.6 c
Rye	None	3,428 a	1.39 a	92 a	23.4 a	2,191 a	1.66 a	69 a	23.0 a
	Low	2,943 a	1.33 a	91 a	22.9 a	2,469 a	1.63 a	69 a	22.9 a
	High	3,144 a	1.29 a	78 a	22.4 a	2,618 a	1.61 a	70 a	24.2 b
Oats	None	3,443 a	0.76 a	62 a	29.7 a	4,488 a	1.16 a	75 a	25.3 a
	Low	3,157 a	0.74 a	67 a	30.0 a	4,498 a	1.27 a	68 a	24.9 a
	High	3,680 a	0.82 a	72 a	28.8 a	4,239 a	1.21 a	70 a	24.5 a

[y] Low = 1.8 g/m^2, high = 3.6 g/m^2.
[z] Means within a small grain and column followed by the same letter are not significantly different using LSD ($P = 0.05$).

RESULTS

In both growing seasons, all small grains except oats were susceptible to take-all, as indicated by the significantly higher disease incidence and disease severity in infested treatments than in the noninfested treatment (Table 1). A few roots from the noninfested and oat treatments had symptoms of take-all. In 1986, low and high infestation levels were significantly different for disease incidence and severity for wheat, barley, triticale, and rye (Table 1). In 1987, low and high infestation levels were significantly different for disease incidence and severity for barley only.

Susceptibility of wheat, barley, and triticale also was indicated by a significant decrease in yield in 1986 and 1987 compared with the noninfested control (Table 2). Yield also was significantly different between low and high infestation levels for wheat and triticale in 1986. Yield components reduced by take-all were tillers per meter for wheat and triticale in 1986 and for wheat, triticale, and barley in 1987, and TKW for wheat, triticale, and barley in both growing seasons. A slight but significant increase in TKW at the high infestation level occurred for rye in 1987. Plant height was reduced by take-all for wheat in 1986 and for wheat, triticale, and barley in 1987. There was a significant interaction between cultivar and inoculum level for plant height for the triticale cultivars in 1987. Low and high infestation levels differed significantly for tillers per meter for wheat in 1986, plant height for triticale in 1987, and TKW for wheat, triticale, and barley in 1986 and barley in 1987.

Wheat was the most susceptible small grain in 1986, as indicated by the disease severity index (Table 3). Triticale was the next most susceptible small grain, with disease severity being significantly less than that for wheat in 1986. Disease incidence between wheat and triticale was not significantly different in either year. Barley was significantly less susceptible than wheat or triticale but more susceptible than rye in both years, as indicated by disease incidence and severity.

Wheat showed significantly greater yield reductions than the other small grains in both growing seasons, except for triticale in 1987 (Table 4). Yield reductions were significantly less for barley than for triticale in 1986. Oats and rye did not differ significantly in terms of percent reduction in yield in either growing season. Wheat showed the greatest reduction in plant height, tillers per meter, and TKW in 1986 and in tillers per meter and TKW in 1987. Wheat, triticale, and barley differed significantly from rye and oats for all plant growth variables, except for relative height reduction between rye and triticale in 1987. Reductions in tillers per meter and plant height were significantly different between rye and oats in 1986, but values for either small grain were not significantly different from no reduction in these variables.

Within each small grain, cultivars did not consistently differ in susceptibility to take-all with the exception of Dawn barley, which had a lower percentage of diseased plants and a lower disease severity index than Volbar in 1986 and Volbar and Sussex in 1987 (Table 3).

Cultivars within a small grain differed in reduction in some of the variables for plant growth for wheat, triticale, and barley (Table 4). In 1986, Stacy and Coker 916 wheat showed less reduction in yield, plant height, and tillers per meter than Twain and Lincoln, except for relative yield loss between Coker 916 and Twain. In 1987, Stacy and Coker 916 had greater yield losses than Florida 301. In 1987, the triticale cultivar Florico showed less yield reduction than the other cultivars tested. Beagle 82 and Florico also had less reduction in plant height and tillers per meter than the other cultivars, except for tiller reduction between Florico and Thomas. Beagle 82 had the greatest reduction in TKW and differed significantly from all cultivars except Florico. Reductions in grain yield and tillers per meter were significantly less for Dawn barley than for Volbar in 1986. In 1987, tiller reduction was lower in Dawn than in Sussex but not in Volbar.

DISCUSSION

The order of susceptibility of the small grains was similar to previous reports (4,5,9–11), with disease severity the greatest in wheat, followed by barley and rye. Differences in small grain susceptibility also were observed in the percentage of plants having symptoms of take-all. Jensen and Jørgensen (5) also found lower disease incidence for barley and rye than for wheat in field studies. This indicates that differences in susceptibility among wheat, barley, and rye are not due solely to differences in disease expression or rate of root growth to compensate for infection, as suggested by Asher (1) and Skou (18), but are true differences in susceptibility. The data indicate that triticale was more similar to wheat in susceptibility than to rye in both disease incidence and severity. This is in agreement with Mielke (10) and Linde-Laursen et al (8) in controlled-environment studies and with Mielke (10) and Nilsson (11) in field studies. However, Hollins et al (2) and Jensen and Jørgensen (5) in field studies found triticale to be intermediate between wheat and rye in disease reaction.

Reduction in grain yield and the other plant growth variables reflected disease reaction of the different small grains. Wheat was the most susceptible small grain and showed the greatest reduction in yield, plant height, tillers per meter, and TKW. Triticale was the next most susceptible small grain and usually followed wheat in reduction in these variables, although reductions were often not significantly different from those for barley. This is in agreement with Jensen and Jørgensen (5), who reported that the order of susceptibility, yield reduction, and reduction in TKW was similar for these small grains. Scott et al (16) also found the order of relative yield loss to be similar to disease reaction for rye, wheat, and triticale.

Generally, only small differences in susceptibility among cultivars within a small grain have been reported, and these differences are often not reproducible (15). In these studies, Dawn barley was found to be less susceptible than the other barley cultivars. Differences in resistance of barley cultivars to take-all have been reported previously (6,11). Although no consistent differences were noted in the susceptibility of the cultivars of the other small grains, significant differences in cultivar performance were noted among the different cultivars of wheat and triticale, as well as barley. With barley, the observed differences in 1986 and 1987 were probably accounted for by the differences in susceptibility of the cultivars. Earliness of cultivar maturity was related to lower reductions in grain yield and the other variables when differences in wheat or triticale cultivars were found. Lincoln and Twain, which head 4–5 days later than Stacy or Coker 916, showed greater reductions in yield, plant height, and tillers per meter than Stacy and Coker 916 in 1986. In 1987, Stacy and Coker 916 had greater yield reductions than Florida 301, which heads 4–5 days earlier. At Byron in 1987, differences in grain yield and the other variables also were observed for the triticale cultivars. Heading dates for this location and growing season were 8, 11, 25, 28, and 28 April for Florico, Beagle 82, Thomas, Councill, and Morrison, respectively. Florico, the earliest maturing triticale cultivar, showed significantly less yield loss than the other cultivars. Stunting and reduction in tillering were also less in the early cultivars Beagle 82 and Florico. Earliness of maturity of a cultivar may be important in minimizing yield losses due to take-all by allowing the host to be further developed before pathogen activity increases as soil temperatures rise in the spring. Earliness of maturity has been reported previously by Pridham (12) to be associated with decreased damage due to take-all on wheat.

Disease was more severe in 1987 than in 1986, and this was reflected in many of the variables. In 1987, only plant height for triticale and TKW for barley were significantly decreased by increasing inoculum level. In 1986, in contrast, increasing inoculum level significantly decreased yield for wheat and triticale, tillers per meter for wheat, and TKW for wheat, triticale, and barley. Greater disease severity in 1987 could have been

Table 3. Severity and incidence of take-all on small grains and small grain cultivars

	1986			1987		
Small grain	Cultivar	Disease severity index[x]	Disease incidence (%)	Cultivar	Disease severity index	Disease incidence (%)
Wheat	Coker 916	3.2 a[y]	93 a	Coker 916	3.8 a	100 a
	Stacy	3.3 a	94 a	Stacy	3.7 a	100 a
	Twain	3.4 a	98 a	Florida 301	3.8 a	100 a
	Lincoln	3.7 a	98 a	Florida 302	3.7 a	97 a
	Combined	3.4 A[z]	96 A	Combined	3.8 A	99 A
Triticale	Morrison	3.0 a	90 a	Morrison	3.5 a	98 a
	Beagle 82	2.8 a	91 a	Beagle 82	3.6 a	100 a
	Councill	2.5 a	80 a	Councill	3.6 a	100 a
	Thomas	2.8 a	87 a	Thomas	3.4 a	99 a
	Wytch	2.7 a	89 a	Florico	3.6 a	100 a
	Combined	2.7 B	87 A	Combined	3.5 A	100 A
Barley	Dawn	1.0 a	55 a	Dawn	2.0 a	83 a
	Volbar	1.7 b	79 b	Volbar	2.7 b	96 b
	Combined	1.3 C	67 B	Sussex	2.8 b	95 b
				Combined	2.5 B	91 B
Rye	Wrens Abruzzi	0.8 a	40 a	Wrens Abruzzi	1.7 a	75 a
	Florida 401	0.9 a	58 b	Florida 401	1.1 b	65 a
	Combined	0.8 D	49 C	Combined	1.4 C	70 C
Oats	Coker 716	0.0 a	1 a	Coker 716	0.0 a	2 a
	Coker 227	0.0 a	0 a	Coker 227	0.0 a	0 a
	Combined	0.0 E	0 D	Combined	0.0 D	1 D

[x] Disease rating scale of 0–4, where 0 = no roots with symptoms and 4 = 75–100% of roots with symptoms.
[y] Means within a small grain and column followed by the same lowercase letter are not significantly different using LSD ($P = 0.05$).
[z] Means in a column followed by the same uppercase letter are not significantly different using LSD ($P = 0.05$).

Table 4. Percent reduction in grain yield, plant height, tillers per meter, and thousand kernel weight (TKW) for small grains and small grain cultivars to take-all compared with noninfested controls

Small grain	1986 Cultivar	Grain yield	Plant height	Tillers/m	TKW	1987 Cultivar	Grain yield	Plant height	Tillers/m	TKW
Wheat	Coker 916	47 ab[y]	17 a	41 a	16 a	Coker 916	79 a	23 a	44 a	25 a
	Stacy	43 a	18 a	36 a	16 a	Stacy	82 a	29 a	42 a	27 a
	Twain	63 bc	27 b	53 b	14 a	Florida 301	71 b	24 a	49 a	32 a
	Lincoln	71 c	32 b	56 b	16 a	Florida 302	73 ab	26 a	55 a	25 a
	Combined	56 A[z]	24 A	46 A	16 A	Combined	76 A	25 A	47 A	27 A
Triticale	Morrison	40 a	16 a	26 a	7 a	Morrison	72 a	25 a	44 a	16 a
	Beagle 82	39 a	11 a	21 a	10 a	Beagle 82	59 a	6 c	0 c	26 b
	Councill	32 a	16 a	22 a	6 a	Councill	73 a	20 ab	43 a	13 a
	Thomas	26 a	7 a	4 a	8 a	Thomas	64 a	17 b	31 ab	15 a
	Wytch	39 a	8 a	26 a	11 a	Florico	42 b	4 c	17 b	23 ab
	Combined	35 B	11 B	19 B	8 B	Combined	62 AB	14 AB	27 B	19 B
Barley	Dawn	5 a	10 a	17 a	8 a	Dawn	33 a	14 a	16 a	12 a
	Volbar	35 b	7 a	34 b	5 a	Volbar	51 a	18 a	19 a	15 a
	Combined	20 C	8 BC	25 B	6 B	Sussex	56 a	20 a	33 b	18 a
						Combined	47 B	17 A	23 BC	15 B
Rye	Wrens Abruzzi	13 a	6 a	10 a	2 a	Wrens Abruzzi	−10 a	1 a	0 a	−6 a
	Florida 401	−6 a	3 a	6 a	1 a	Florida 401	−20 a	3 a	−4 a	0 a
	Combined	3 D	5 C	8 C	1 C	Combined	−15 C	2 BC	−2 D	−3 D
Oats	Coker 716	−9 a	−21 a	−14 a	−4 a	Coker 716	−6 a	−12 a	8 a	6 a
	Coker 227	−4 a	8 b	−1 a	2 a	Coker 227	5 a	−4 b	2 a	−1 a
	Combined	−6 D	−7 D	−7 D	−1 C	Combined	−1 C	−8 C	5 CD	3 C

[y] Means within a small grain and column followed by the same lowercase letter are not significantly different using LSD ($P = 0.05$).
[z] Means in a column followed by the same uppercase letter are not significantly different using LSD ($P = 0.05$).

due to a number of factors, including greater inoculum potential, a more favorable environment for disease development, and a different soil type.

The data suggest that any of these small grains are preferable to wheat in terms of performance under naturally infested field situations. Rye and oats were the only small grains that performed similarly in infested and noninfested soils. The relatively good performance of barley may have been due in part to the cultivars used, since the barley cultivars differed in disease reaction. The effect of these small grains when used in rotations with wheat in double-cropping systems on maintaining or increasing inoculum of *G. g.* var. *tritici* for subsequent wheat crops needs to be addressed before effective rotations can be recommended.

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