Field Resistance of Oats to *Puccinia graminis* f. sp. *avenae* Measured via Yield and Seed Weight Reduction

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ABSTRACT

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To determine whether currently grown, seedling-susceptible oat (*Avena sativa*) lines varied in field resistance to stem rust (*Puccinia graminis* f. sp. *avenae*), we tested 150 lines in the field in 1982 and 240 in 1983 and 1985. Data were expressed as resistance indexes obtained by dividing yields and 200-seed weights of diseased plots by corresponding values from rustfree plots. Infection and resulting damage were severe. Ranges of resistance indexes for yield were 0.11–0.76, 0.23–0.84, and 0.32–0.99 in 1982, 1983, and 1985, respectively. Corresponding ranges of resistance indexes for seed weight were 0.23–0.66, 0.34–0.68, and 0.40–0.79. Variation among lines for indexes was significant ($P = 0.01$) in all 3 yr.

Additional key words: disease tolerance, slow rusting

Stem rust (caused by *Puccinia graminis* Pers. f. sp. *avenae* Eriks. & E. Henn.) can cause significant reductions in yield and grain quality of oats (*Avena sativa* L.). A comprehensive review of this subject was made by Martens (12). Representative work includes that of Rothman and Frey (19), who showed that yield of susceptible varieties could be reduced by 25%, and Martens (11), who estimated rust-caused losses of 35% of the potential production in Manitoba and eastern Saskatchewan in 1977.

In recent years, there has been much interest in field resistance for controlling rust diseases of small grains. Qaydum and Line (17) showed that slow-rust development (a manifestation of field resistance) on wheat (*Triticum aestivum* L.) cultivars containing mature resistance to stripe rust (*P. striiformis* West) occurred for all races of the pathogen tested. This type of resistance remained effective against all races of *P. striiformis* for 20 yr. On the other hand, specific resistance has seldom remained effective for more than a few years. Hartleb and Gerlach (6) reported that one line of barley (*Hordeum vulgare* L.) with "moderate resistance" to leaf rust (*P. hordei* Otth.) showed no yield reduction in 3 yr of field testing in environments where susceptible cultivars sustained up to 30% loss. Rees and Syme (18) found that severe epidemics of wheat stem rust (*P. g.* f. sp. *tritici*) reduced yield of susceptible cultivars by 50% in Australia but caused no yield loss on slow-rusting cultivars.

Frey (3) found that a number of artificially induced mutant oat lines were more resistant to stem rust than was the parent material, but some were more susceptible. He later reported that mutant lines derived from X-rayed Huron oats showed a range of resistance, indicating a complex type of inheritance

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(4). Kounovski and Breshkov (9) showed that 14% of 326 oat accessions tested were resistant to stem rust under field conditions in Bulgaria. Manisterski (10) found that the slow-rusting type of resistance of oats was the most important factor in the defense of *A. sterilis* against stem rust in Israel. Such resistance was stable and gave effective protection in genetically uniform host populations in field plots.

This study was conducted to evaluate currently grown oat cultivars and adapted breeding lines for field resistance to stem rust via their quantitative yield and seed weight reductions when subjected to a field epidemic.

MATERIALS AND METHODS

The host materials used in this study included 150 advanced oat breeding lines and cultivars (adapted to central Iowa) in 1982 and 240 such lines and cultivars in 1983 and 1985. All lines were susceptible in the seedling stage to stem rust race NA-27. The oat lines were evaluated in randomized block designs with eight replicates in 1982 and 1983 and six replicates in 1985. Each plot consisted of a hill (5) sown with 30 seeds, and hills were spaced 30.5 cm apart in perpendicular directions. Epidemics of *P. g.* f. sp. *avenae* were initiated by hypodermically injecting about 0.05 cc of an aqueous suspension of urediniospores of race NA-27 into one culm per hill as soon as culms started to elongate.

Duplicate plots separated from the diseased plots by 2-m alleys were protected from disease development by applications of maneb four to six times per season at a rate of 1 kg a.i./ha per application. Resistance indexes were obtained for each diseased plot by dividing its yield and 200-seed weight by the means of yield and 200-seed weight, respectively, from all replicates of the same line maintained in the maneb-treated plots. Reductions in yield and seed weight are regarded as good measures of response of the host to rust infection (16,20).

RESULTS

Rust-controlled check plots. Plot yields of check cultivars indicated that overall growing conditions were poor in 1982, mediocre in 1983, and excellent in 1985. The analysis of variance showed that there was significant ($P = 0.05$) variation among the oat lines for yielding ability in the absence of rust during each year.

Even though sprayed plots were close to the rusted plots, they remained virtually rustfree as a result of the protection afforded by the maneb sprays. Scattered rust pustules occurred, but they had no measurable effect on the plants; therefore, yields and 200-seed weights from these rustfree control plots were considered good estimates for the lines in the absence of rust.

Responses to infection. In 1982, stem rust developed early and caused severe damage. Overall mean yields and 200-seed weight measurements were reduced 75 and 60%, respectively, by stem rust. Mean indexes of individual lines ranged from 0.11 to 0.76 for yield and from 0.23 to 0.66 for seed weight. The lower values represent virtually total destruction in terms of a commercially harvestable crop. Analyses of variance resulted in F values for line variation highly significant for both yield and seed weight indexes. Thus, there were significant differences for quantitative responses to infection among the 150 lines tested in 1982.

Rust infection was not as damaging in the plots in 1983 and was still less damaging in 1985. A combined analysis of yield and 200-seed weight indexes for 1983 and 1985 resulted in significant ($P = 0.0001$) variation among lines for reduction in both traits attributable to rust infection. The interaction of years and lines was significant also. The oat lines that were significantly ($P = 0.01$) higher and lower than the overall mean of the experiment over years are given in Table 1. Nearly all lines that had significantly greater 200-seed weight indexes than the experiment mean over years also were significantly higher for seed weight indexes only in 1983 and in

Table 1. Stem rust (*Puccinia graminis* f. sp. *avenae*) resistance indexes[a] for yield and seed weight 1983 and 1985 for selected oat lines[b]

Cultivar or selection	Rustfree (yield [g/plot])		Rusted: Seed weight index		Rusted: Yield index	
	1983	1985	1983	1985	1983	1985
Y891-1-1	19.1	28.0	0.690	0.719	0.830	0.720
Y891-1-22	19.9	24.5	0.646	0.767	0.692	0.986
Y967-1-1	23.0	40.0	0.568	0.775	0.386	0.538
Y881-1-1	20.9	31.0	0.576	0.699	0.581	0.780
Y928-1-4	23.4	40.5	0.583	0.649	0.540	0.568
Y955-1-7	26.2	28.0	0.595	0.710	0.486	0.988
Y894-1-5	29.4	34.0	0.575	0.731	0.477	0.662
Y959-1-11	32.2	28.0	0.571	0.728	0.442	0.726
Y894-1-6	21.0	30.0	0.599	0.707	0.738	0.678
Y922-1-3	25.8	38.0	0.572	0.724	0.490	0.539
Y946-1-4	20.2	28.0	0.613	0.686	0.802	0.756
MN81135	25.0	31.5	0.571	0.692	0.525	0.519
Y913-1-17	23.9	36.5	0.597	0.695	0.771	0.561
Cherokee	25.9	38.5	0.546	0.709	0.531	0.576
MN81229	30.2	36.5	0.554	0.751	0.459	0.689
WIx3530.47	24.4	32.0	0.547	0.727	0.651	0.682
Y876-1-2	22.6	31.0	0.587	0.653	0.530	0.522
Y884-1-3	25.4	32.0	0.562	0.714	0.616	0.604
Y876-1-10	19.6	28.0	0.560	0.684	0.452	0.571
Y931-1-2	22.4	29.5	0.570	0.699	0.598	0.593
Y872-1-7	19.5	43.0	0.574	0.690	0.590	0.461
MN80116	35.0	39.5	0.571	0.709	0.539	0.544
Y924-1-2	25.2	35.0	0.559	0.730	0.624	0.695
Y873-1-8	28.5	42.0	0.545	0.725	0.553	0.468
Y906-1-18	22.0	33.0	0.590	0.639	0.636	0.556
Y876-1-11	20.6	44.5	0.608	0.652	0.709	0.367
Y873-1-9	25.2	44.0	0.610	0.657	0.663	0.439
MN81132	27.0	30.0	0.573	0.679	0.519	0.544
Y875-1-20	19.5	42.5	0.576	0.672	0.692	0.443
B605-447	18.5	26.5	0.563	0.653	0.682	0.824
MN81128	30.1	37.5	0.557	0.669	0.444	0.489
Y895-1-8	27.6	30.5	0.588	0.648	0.679	0.656
Y906-1-7	26.5	34.0	0.542	0.702	0.547	0.461
Y917-1-6	17.0	26.0	0.557	0.668	0.728	0.756
Y929-1-5	20.5	38.0	0.578	0.635	0.488	0.412
Y936-1-12	20.2	53.5	0.561	0.643	0.648	0.352
IL79-1178	33.6	37.0	0.453	0.492	0.461	0.450
B657-170	24.8	46.5	0.412	0.509	0.455	0.416
Gopher	20.6	32.0	0.399	0.564	0.307	0.583
Ogle	30.2	47.5	0.361	0.547	0.300	0.519
Lancer	20.5	35.5	0.382	0.526	0.348	0.469
D206-2-78	28.2	38.5	0.394	0.514	0.398	0.407
Porter	22.0	45.5	0.381	0.546	0.534	0.355
Clinton	33.0	51.5	0.396	0.317	0.230	0.492
OA501-1	15.5	20.0	0.326	0.402	0.339	0.350
Mean of exp.	28.2	36.5	0.501	0.629	0.498	0.557
LSD ($P = 0.05$)	7.2	15.5	0.049	0.059	0.162	0.157

[a] Indexes were calculated by dividing the value for a rusted plot by the mean of the corresponding rustfree plots.

[b] The lines shown are all those with mean 2-yr seed weight indexes significantly ($P = 0.01$) higher than the overall mean and the nine with the lowest 2-yr mean seed weight indexes.

1985. In 1983, 200-seed weight indexes of the 240 oat lines ranged from 0.33 to 0.68, with 31 lines above and 33 lines below the experiment mean. Yield indexes ranged from 0.23 to 0.84. In 1985 when rust incidence was less severe, 200-seed weight indexes ranged from 0.40 to 0.79, with 20 lines above the mean ($P = 0.01$) and 25 below it. Yield indexes ranged from 0.32 to 0.99.

In general, oat cultivars withstood stem rust infection poorly regardless of how long ago they were released; i.e., they had low yield and 200-seed weight indexes. Cherokee, widely grown in the 1950s, was the only cultivar that had a significantly higher index than the mean of the experiment for 200-seed weight in both 1983 and 1985. On the other hand, several cultivars currently widely grown sustained significantly more damage from stem rust than the experiment mean over years. For example, Ogle and Lancer had mean 200-seed weight indexes of 0.45, whereas the experiment mean was 0.57.

Correlations. A relationship between inherent yielding ability in a rustfree environment and field resistance to stem rust infection would be of considerable interest for use in resistance breeding programs. In 1983 and 1985, the correlations between rustfree yield and 200-seed weight index were -0.162 and -0.318, respectively. These low associations suggest that there is little relationship, if any, between yielding ability and field resistance to stem rust.

Long-season oat cultivars may be more subject to damage by stem rust than early-maturing ones. However, the correlations between heading date and 200-seed weight index in 1983 and 1985 were -0.393 and -0.063, respectively. Field resistance to stem rust and heading date were not strongly correlated with date of maturity.

DISCUSSION

All oat lines used in this study were susceptible in the seedling stage to race NA-27 of *P. g.* f. sp. *avenae*. Also, in our epidemic environments, all lines appeared susceptible as mature plants in the field. It is probable that they differed in the numbers of pustules per unit area of leaf or stem, latent period, or some other factor that operated to give field resistance (e.g., slow rusting) to the stem rusts. In any event, it would not have been possible to differentiate among them on a visual scale. Therefore, the differences in reduction in yield and seed weight among lines probably could not have been detected by any method other than measuring the effects of the disease on productivity traits. Differences in productivity among the oat lines were sufficiently large to be of value in breeding for rust resistance.

A significant question relates to the mode of inheritance of this resistance type. Field resistance (or slow rusting) to stem rust of wheat may be inherited as a quantitative character (8,13). However, the degree of resistance conditioned by certain resistance genes may be determined by a complex interaction of genotype with environment (7). Therefore, the existence of a continuous range of responses to rust infection does not prove that the resistance is complexly inherited. Recently, Brodny et al (2), working with isogenic lines of wheat with one, two, or three defeated stem rust resistance genes, found increasing reductions in pustule size and amounts of sporulation strongly correlated with increasing numbers of these defeated genes.

In view of the diversity of parentage, the various oat lines probably possessed different genes for resistance. Such was reported by Milus and Line (14), who showed that genes conditioning mature plant resistance to stripe rust in the Luke cultivar of wheat differed from those in Gaines and Nugaines.

There is a question as to whether the ranking of lines when tested under conditions of heavy inoculum would be the same as when they were tested under lighter spore loads. Nazareno and Roelfs (15) found that the adult plant resistance to stem rust in Thatcher wheat was sensitive to inoculum density. Nevertheless, they concluded that this trait could be selected successfully under conditions of heavy inoculum density. Andres and Wilcoxson (1) also showed that the rankings of lines of barley for slow rusting to *P. hordei* were similar under epidemics of different severity. Differences among lines, however, were more distinct under conditions of severe rust development.

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