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Competitive Abilities of Oat and Barley Varieties[1]

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Competitive ability of a plant genotype reflects its capacity to yield well and compete successfully for light, moisture, and nutrients when grown with similar or dissimilar genotypes. This trait is important to plant breeding because most breeding populations are propagated in mixed or competitive stands. The objective of this study was to assess the competitive abilities of oat and barley genotypes.

Two sets of oat and barley genotypes were evaluated for competitive ability. Set I consisted of five oat varieties, and Set II consisted of two barley and three oat varieties. Neither set, when averaged, showed over- or under-compensation with respect to competitive ability. Genotypes within a set were highly variable for mean competitive ability, and the effects of competition were even more variable for individual pairs. In the set with barley and oats, a competitive advantage or disadvantage shown by an entry tended to be consistent across competitors.

Competitive advantages or disadvantages displayed by oat and barley genotypes for biomass and grain yield usually could be related to components of biomass or grain yield, respectively. Increases in biomass and grain yield were reflected in significant increases in numbers of spikelets, primary and secondary florets, and tillers per plant. Competitive advantages and disadvantages were greatest in the interspecific comparisons.

INDEX DESCRIPTORS: Oat, barley, competition.

Competitive ability as applied to plants is defined as a genotype's capacity to yield well and compete successfully for light, moisture, and nutrients when surrounded by similar or dissimilar genotypes (Francis, 1981). Positive associations between high grain yields in pure stand and high competitive ability in mixtures have been reported for barley (*Hordeum vulgare* L.) (Allard and Adams, 1969; Harlan and Martini, 1938), wheat (*Triticum aestivum* L.) (Allard and Adams, 1969; Jensen and Federer, 1964), and maize (*Zea mays* L.) (Kannenburg and Hunter, 1982). Also, negative relationships between grain yield in pure stand and competitive ability in mixture were reported for barley (Wiebe et al., 1963) and rice (*Oryza sativa* L.) (Jennings and de Jesus, 1968)

Schutz and Brim (1967) defined four types of intergenotypic competition: under-compensation, complementary compensation, neutral or no compensation, and over-compensation. McBratney and Frey (unpublished data) found that two sets, each with five near isolines of oat (*Avena sativa* L.), showed over-compensation of 3% and 9% for biomass when tested for competitive ability in all possible binary combinations. These represent instances of over-compensation.

Competitive ability of plant genotypes is a trait of great importance to plant breeding because most segregating populations that result from hybrids are propagated in mixed or competitive stands. Thus, competitive abilities of genotypes can have a marked influence on the results of a breeding program. Therefore, we conducted competition studies with oat and barley varieties to determine (a) whether competition among varieties and species displayed a range of competitive abilities, (b) what types of competition would occur among diverse genotypes, and (c) whether competitive ability was related to yield components.

MATERIALS AND METHODS

Materials and Competition Experiments

Two sets each with five genotypes were used for the competition experiments. Set I consisted of five midseason oat varieties; Benson (CI 9358), Chief (CI 9080), Garland (CI 7453), Nobel (CI 9194), and Ogle (CI 9401). Set II consisted of three oat, Cherokee (CI 3846), Richland (CI 787), and CI 9268, and two barley, Minnesota M32 and Wisconsin 38 (CI 5105), genotypes.

Oat and barley genotypes in Sets I and II were evaluated for competitive abilities in field experiments in 1982 and 1983 (Figure 1). That is, each genotype in a set was tested against all other genotypes in the set, taken one at a time. Plants of one genotype were sown in the center of each of paired hexagon plots following the arrangement suggested by Sakai (1955). The center plant in a plot was surrounded by two rows of plants, with its own genotype (A^A) (pure stand) in one plot and another genotype (A^N) (mixed stand) in the paired slot. The inner and outer rows of competition contained six and 12 plants sown 5.5 and 11.5 cm, respectively, from the center plant. The arrangement and number of oat or barley seedlings in a plot gave a stand equivalent to 300 plants m^{-2}, the density commonly used in agricultural production. The design was a split-plot, with the two paired hexagonal subplots being randomized within each whole plot. Each set was evaluated in a separate experiment in each year by using a randomized complete-block design with 10 replications.

Water-soluble, polyethylene oxide sheets were used to facilitate sowing plots in the field. A map of the planting arrangement (Figure 1) for one subplot was drawn on paper, and a 30×30 cm sheet of transparent, polyethylene oxide was placed over the map. Next, three seeds were placed at each point on the map. The polyethylene sheet was moistened with a fine mist of water, and a second sheet was placed over the arranged seeds so that the top and bottom sheets stuck together and held the seeds in place. The laminated plastic sheets were then labelled and stacked in boxes for planting.

To plant a plot in the field, a steel rake was used to remove soil to a 5-cm depth from an area large enough to accommodate the 30×30 cm plastic sheet. The laminated plastic sheet with the prearranged seeds was placed in the excavated area and covered with soil. When seedlings were in the two-leaf stage, they were thinned to one seedling per point as shown in Figure 1. At this time, a rubber ring was placed around the base of the test plant to assure its identity at harvest.

The experiments were sown on 22 April 1982 and 23 April 1983 on a Coland loam (Cumulic Haplaquolls) soil at the Hinds experimental farm near Ames, Iowa. The fertilization regime in 1982 was a split application of N, P_2O_5, and K_2O topdressed onto the plots at rates of 28, 8, and 14 kg/ha, respectively, on 25 April; 17, 17, and 17 kg/ha, respectively, on 21 June; and 11, 10, and 10 kg/ha, respectively, on 1 July. In 1983, the rates of application were 28, 8, and 14 kg/ha, respectively, on 25 April; 17, 5, and 8 kg/ha, respectively, on 13 June; and 11, 3, and 6 kg/ha, respectively, on 25 June. Irrigation was used in both years to assure that the experimental areas were never deficient in available moisture. Each year, the plants were sprayed with dimethoate at weekly intervals from emergence to anthesis to control

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aphids and leafhoppers and with Maneb at weekly intervals from anthesis to maturity to control foliar diseases. The plots were hand-weeded.

Collection of Data

Data were collected for the center plant of each plot. At maturity, the test plant was harvested at ground level and dried. Biomass was recorded as the dry weight (in g) of the harvested plant from a plot, after which the number of culms was counted. The number of spikelets for each barley or oat plant was recorded, and for the oat plants, the numbers of primary and secondary florets (seeds) were counted. The seeds from a plant were then weighed to obtain grain yield (in g).

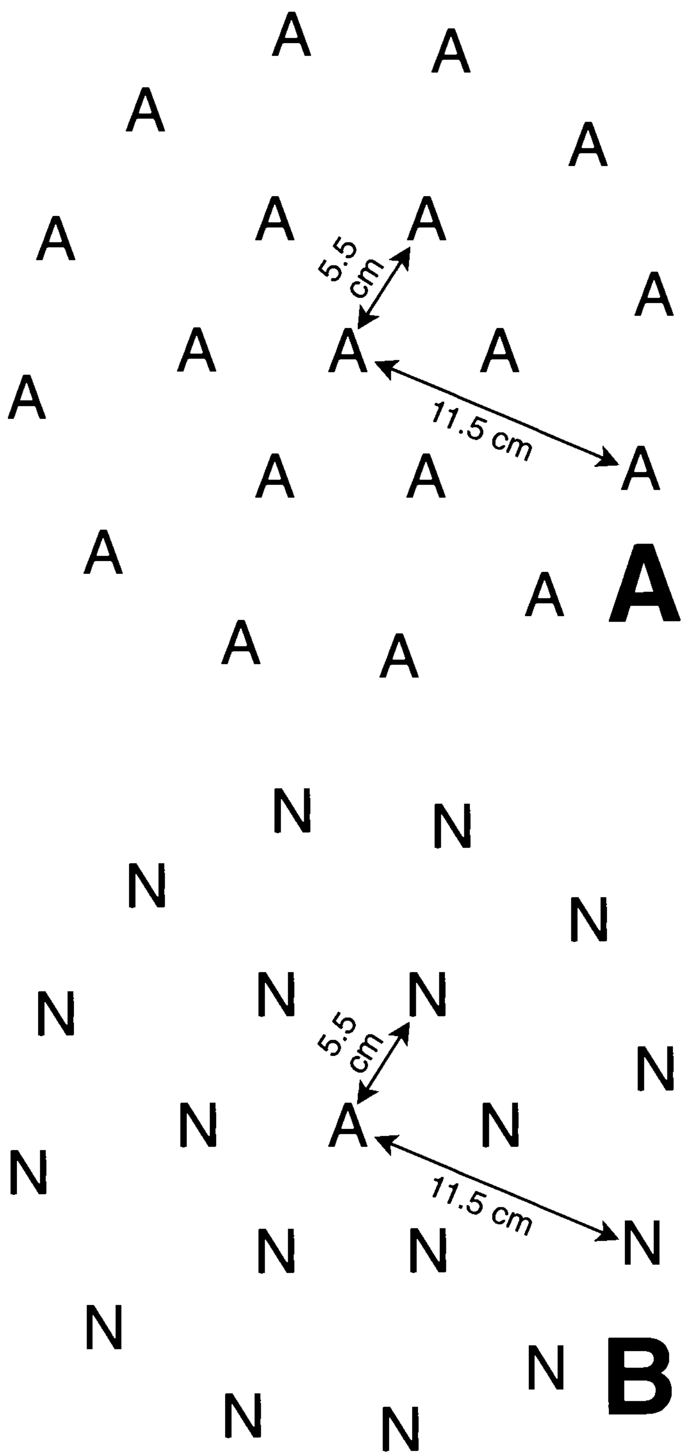

Fig. 1. The planting arrangement used for the two subplots in a whole plot; the center plant in a plot was surrounded by two rows of plants of its own genotype (A) in one plot and of another genotype (B) in the paired plot.

Statistical Procedures

Means for a trait when a genotype was competing with itself and with another genotype were computed across replications and years, and the paired means were tested for similarity by a t-test as follows:

$$t = \frac{\overline{X}_c - \overline{X}_p}{\sqrt{\frac{\sigma_c^2}{n_1} + \frac{\sigma_p^2}{n_2}}},$$

where $\overline{X}_c$ is the mean of the genotype in competitive stand, $\overline{X}_p$ is the mean of the genotype in pure stand, σ_c^2 and σ_p^2 are the variance of the genotypes in competitive and pure stands, respectively, and n_1 and n_2 are the number of observations for competitive and pure stands, respectively.

RESULTS

To determine the mean competitive ability of an entry, relative to other entries in its groups, we computed the mean difference between its performance when grown in a competitive (C) stand with another entry and when grown in pure (P) stand. The means and ranges of differences for all comparisons involving a given entry are presented in Tables 1 and 2 for Sets I and II, respectively.

Set I

When Benson was measured for competitive ability against the other four oat varieties, the mean effect on biomass was zero (Table 1). Grain yield per plant for Benson was variable, but its mean increase of 0. 1 g per plant in competitive stands was caused perhaps by an increase in number of spikelets (5.0) and primary (3.0) florets. Grain yield decreased when Chief and Ogle were the competitors and increased when Garland and Noble were the competitors.

On average, grain yield and yield component traits of Chief were unaffected or only slightly decreased in competitive stands. Thus, when tested against the other varieties as competitors, Chief was a neutral competitor.

Biomass of Garland was reduced, on average, 0.4 g per plant in competitive stands, but a major portion of this decrease occurred when Noble was the competitor. The biomass decrease for Garland when Noble was the competitor was accompanied by a decrease of 0.6** tillers per plant. Grain yield of Garland decreased when Benson, Chief, and Noble were the competitors and increased when Ogle was the competitor. The slight mean decrease in grain yield seemed due to decreased spikelet number. The average decrease in spikelet number (4.0) was reflected in average decreases of 1.0 and 2.0 in numbers of primary and secondary florets, respectively.

Mean biomass of Noble was increased slightly by competition from other varieties, but there was no mean change in grain yield. Number of spikelets, primary and secondary florets, and tillers per plant were virtually unaffected by competition. These traits did show a slight increase when Ogle was the competitor.

Mean biomass of Ogle increased by 0.3 g per plant in competitive stands, but no increase occurred for grain yield. Ogle was inferior in

*, **, and *** denote differences between means of pure and mixed stands were significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 1. Means and ranges of the differences for biomass, grain yield, and numbers of spikelets, primary florets, secondary florets, and tillers per plant, when the entries in Set I were grown in competitive and pure stands.

	Trait					
	Biomass	Grain yield	Spikelets	Primary florets	Secondary florets	Tillers
Entry	(g)	(g)	(no.)			
Benson						
Mean	0.0	0.1	5	3	0	0.2
Range	-0.7 -0.6	-0.6 -0.5	-8 -10	-1 -10	-8 -7	0.0 -0.3
Chief						
Mean	0.0	-0.1	0	-1	-1	-0.1
Range	-0.3 -0.3	-0.3 -0.1	-7 -6	-6 -4	-5 -1	-0.4 -0.1
Garland						
Mean	0.4	-0.1	-4	-1	-2	-0.1
Range	-1.2 -0.4	-0.6 -0.4	-14 -10	-11 -13	-7 -7	-0.6 -0.2
Noble						
Mean	0.2	0.0	-1	0	-1	-0.1
Range	-0.5 -0.8	-0.2 -0.3	-6 -4	-2 -4	-3 -3	0.0 -0.1
Ogle						
Mean	0.3	0.0	2	4	3	0.1
Range	-0.1 -0.5	-0.2 -0.4	-4 -9	-2 -12	-3 -11	-0.3 -0.4

competitive stands only when Benson was the competitor. All the yield-related traits, number of spikelets, primary and secondary florets, and tillers per plant, increased somewhat in competitive stands. Number of primary and secondary florets increased 12.0* and 11.0*, respectively, when Garland was the competitor for Ogle.

Overall, no one variety in Set I was significantly superior in competitive stands, but, usually, Garland was somewhat inferior. Generally, instances of superiority for grain yield were associated with increased number of spikelets and primary and secondaty florets.

Set II

Two barley and three oat varieties were used in Set II. This combination of entries was chosen to compare interspecific competitive abilities.

Mean biomass of Cherokee was decreased 0.4 g per plant (Table 2), but most of this decrease was due to its inferiority when M32 barley was the competitor. Grain yields of this variety were both increased and decreased in competitive stands with the other four entries, but, on average, the effect of competition was zero. There was a general

Table 2. Means and ranges of the differences for biomass, grain yield, and numbers of spikelets, primary florets, secondary florets, and tillers per plant, when the entries in Set II were grown in competitive and pure stands.

	Trait					
	Biomass	Grain yield	Spikelets	Primary florets	Secondary florets	Tillers
Entry	(g)	(g)	(no.)			
Cherokee						
Mean	-0.4	0.0	-1	-3	-1	-0.1
Range	-2.0 -0.6	-0.6 -0.4	-14 -6	-14 -4	-10 -6	-0.6 -0.2
CI 9268						
Mean	0.6	0.4	9	8	5	0.3
Range	-0.9 -1.7	-0.4 -0.8	-6 -17	-7 -17	-9 -14	-0.1 -0.6
M32						
Mean	0.7	0.2	6	—	—	0.5
Range	0.2 -1.7	0.1 -0.5	1 -13	—	—	0.4 -0.7
Richland						
Mean	0.4	0.0	-3	-2	-2	-0.1
Range	-1.8 -1.8	-0.9 -0.8	-36 -22	-31 -14	-32 -17	-0.7 -0.4
W38						
Mean	-0.9	-0.5	-7	—	—	-0.3
Range	-3.4 -1.6	-1.5 -0.7	-21 -2	—	—	-0.7 -0.1

decrease in all yield components of Cherokee, but when M32 was the competitor, significant reductions occurred in number of spikelets and primary florets. Number of tillers per plant was reduced 0.6* when M32 was the competitor of Cherokee, which may have caused the biomass decrease.

Over all comparisons, mean biomass of CI 9268 increased 0.6 g per plant in competitive stands. This trait was significantly increased (1.7* g) when Cherokee was the competitor. Mean grain yield of CI 9268 was 0.4 g per plant greater in competitive than in pure stands, and the mean increase seemed to be caused by increased number of spikelets (9.0) and primary and secondary florets. Spikelet number of CI 9268 increased significantly (17.0* and 12.0*) when Cherokee and M32, respectively, were the competitors, and secondary florets increased by 14.0* when Cherokee was the competitor. Tiller number was significantly increased (0.6*) when M32 was the competitor.

Mean biomass of M32 increased 0.7 g per plant in competitive stands, but much of this increase was due to the 1.7**-g increase when Cherokee was the competitor. On average, grain yield increased 0.2 g per plant. M32 gave greater biomass and grain yield in competitive stands with all other entries. The grain yield superiority of M32 in competitive stands was due to 6.0 more spikelets per spike. The superiority for this trait was 13.0** when CI 9268 was the competitor. Averaged across all four competitors, tillers per plant increased 0.5, and this trait was increased significantly (0.6** and 0.7**) when Richland and W38, respectively, were the competitors.

Mean biomass of Richland decreased 1.8*** g per plant and increased 1.8* g per plant when Cherokee and M32, respectively, were the competitors, but overall, this trait was increased 0.4 g per plant in competitive stands. Biomass superiority was not reflected in grain yield superiority in competitive stands. Number of spikelets and primary and secondary florets were decreased somewhat in competitive stands. Tillers per plant decreased significantly (0.7***) when Cherokee was the competitor for Richland and this resulted in a decrease in biomass.

Averaged over four comparisons, competition caused decreased biomass, grain yield, and yield related components for W38 barley. Mean biomass decreased 0.9 g per plant or about 20%. Major decreases occurred when Cherokee and Richland (1.6** g and 3.4** g per plant, respectively) were the competitors. These two varieties also affected grain yield and spikelet number similarly. Overall, tillers per plant were reduced 0.3, but when Richland was the competitor, this trait was decreased 0.7**.

Most noticeable in Set II was that competition among the five entries resulted in much greater changes in trait expression than occurred in Set I where only oat varieties were used as competitors. Of the two barley varieties, M32 was a strong and W38 was a weak competitor. Biomass, grain yield, and number of spikelets increased when M32 was grown in competitive stands, whereas these traits decreased for W38. The oat variety CI 9268 was a strong competitor. Its biomass, grain yield, and yield related traits increased in competitive stands. The oat varieties Cherokee and Richland generally were neutral as competitors. They showed decreased number of spikelets and primary and secondary florets in competitive stands, with no change in grain yields and either plus or minus changes in biomass.

DISCUSSION

Competitive ability of a plant genotype is determined by the interaction of many plant traits. Lee (1960) found that the competitive advantage of Atlas over Vaughn barley was due to greater tiller production and survival, whereas Khalifa and Qualset (1974) found that competitive advantage in wheat was related to plant height. Competitiveness of rice genotypes in mixtures was associated with plant height and tillering ability (Jennings and de Jesus, 1968). However, varietal survival in mixtures of barley (Edwards and Allard, 1963; Lee, 1960; Suneson, 1949), soybeans (Mumaw and Weber, 1957), and rice (Jennings and de Jesus, 1968) have shown no positive relationship between yielding ability of a genotype in pure stands and its survival in mixed stands.

Sakai and his colleagues (Sakai, 1955; Sakai and Gotoh, 1955; Sakai and Suzuki, 1955a,b) concluded that, for barley and rice, competitive ability was an inherited trait independent of any other trait measured. Schutz and Brim (1967) identified four categories of competitive relationships among soybean varieties, neutral, complementary, under-compensation, and over-compensation. Competitive ability of one rice genotype may cause a decline or complete elimination of another genotype from a mixture (Jennings and de Jesus, 1968; Oka, 1960).

Sets I and II of genotypes in our study, overall were neutral in their competitive relationships. The genotypes within a set were highly variable with respect to mean competitive reaction. Changes in mean biomass due to competition when oat and barley varieties were evaluated ranged from a 24% reduction for W38 barley to a 25% increase for M32. And, the oat varieties Cherokee, CI 9268, and Richland had mean biomass changes due to competition of −13, 22, and 15%, respectively. Biomass changes for the five oat varieties in Set I ranged from −14 to 10%. When oat and barley varieties were tested, however, the competitive advantage or disadvantage shown by an entry tended to be consistent across all competitors. For example, the biomass of W38 barley was reduced by three of the four competitors, and the reductions were significant when Cherokee and Richland oat varieties were its competitors. The increase in biomass for M32 barley resulted from this entry showing a competitive advantage over all four of its competitors.

There is no theory upon which to base an expectation about the types of competitive ability that should be expected for plant genotypes. First and foremost, the competitive ability of a genotype can be evaluated only relative to the genotypes that serve as competitors. Thus, Atlas barley, which has a consistent and marked competitive advantage over Vaughn variety (Lee, 1960), might not have a competitive advantage if the competitor was a different genotype. Mixtures of small grain varieties tend to give from 0 to 5% increases in grain yield over the mean of the component genotypes grown in pure stand (Jensen, 1952; Frey and Maldonado, 1967).

In this study, competitive advantages or disadvantages displayed by oat and barley genotypes for biomass and grain yield usually could be related to components of biomass and grain yield. Biomass of Richland decreased and increased 95% when grown with Cherokee and M32, respectively, in competitive stands. A significant decrease in tillers (58%) resulted when Cherokee was the competitor of Richland. This was reflected in decreases of 90%, 150%, 148%, and 168% for grain yield and number of spikelets and primary and secondary florets, respectively. A 31% increase in tillers per plant when M32 was the competitor of Richland resulted in a 95% increase in biomass. Secondarily, grain yield increased 64% and number of spikelets and primary and secondary florets increased 76%, 52%, and 74%, respectively. Thus, all competitive effects of M32 upon Richland more or less emanate from the effect on tillering.

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