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Diallel Analysis of Early Competition between Sweet Corn and Four Weed Species[1]

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Abstract. **The early competitive relationships of sweet corn (*Zea mays* L.), barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), common lambsquarter (*Chenopodium album* L.), and redroot pigweed (*Amaranthus retroflexus* L.) during the first 4 weeks of growth were studied in the greenhouse using a modified diallel analysis. Heights of individual plants at 2, 3, and 4 weeks after seeding were measured as well as dry weights at 4 weeks. Analyses indicate that sweet corn was the most competitive species. Barnyardgrass offered the most competition to sweet corn relative to the other weed species which offered much less competition to sweet corn and comparable competition to each other. Competitive relationships remained fairly constant over time with perhaps a slight increase in the competitive ability of crabgrass. A slight increase in compatibility between sweet corn and barnyardgrass, and between crabgrass and pigweed occurred during the 4th week of growth.**

In a recent survey (1), barnyardgrass, crabgrass, lambsquarter, and pigweed were rated among the 10 most common weeds in sweet corn. A Canadian study suggested that weed competition in sweet corn was critical between the 2nd and 4th weeks of growth (2).

This study was designed to study the early competitive relationships between 'Iochief' sweet corn, barnyardgrass, large crabgrass, common lambsquarter and redroot pigweed under greenhouse conditions.

Materials and Methods

Species were seeded in all possible interspecific pairs (without reciprocals) in 20 cm plastic pots (experimental units) filled to within 2.5 cm of the top with steamed potting soil and placed on 20 cm centers. They were seeded 1 cm deep in 16 sites per pot with 8 alternate sites per species. Sites were arranged in a circle with 1.9 cm between sites. Ten seeds per site were planted except for sweet corn of which 3 kernals per site were planted. Experimental design was a randomized complete block with 4 replications. Block and treatment effects were considered fixed and absence of block × treatment interaction was assumed. All species were thinned to 1 plant per site after 1 week of growth.

Temperatures were maintained at 32°C (day) and 18° (night). Photoperiod was 16 hr and was supplemented and extended with mercury vapor lamps. Plants were given sufficient water and nutrients to promote thrifty growth.

Height of individual plants was measured 2, 3, and 4 weeks after seeding. Dicotyledonous species were measured to the top of the plant. Monocotyledonous species were first gathered into a vertical position and then measured to the tip of the longest leaf. Plants were harvested at 4 weeks, dried in a forced-draft oven for 1 week at 82°C and then weighed. Within-pot mean heights and dry weights for each species were computed.

Data were collated (Table 1) so that for a particular replication (r), a particular pot (x) in the experiment represented 2 experimental units: 1) the yield of species i in association with species j (x_{ijr}) and 2) the yield of j in association with i (x_{jir})[3]. This arrangement conforms to Griffing's Method 3, model I diallel analysis (4) and Williams' analysis of between-pot and within-pot competition (5).

Sources of variation in Griffing's analysis are general combining ability, specific combining ability, reciprocal effects and error. For a competition analysis, general combining ability can be renamed general competitive ability (g). The g value for a particular species (i) is dependent on 2 components: 1) $x_{i.}$ which measures the ability of i to compete with other species and 2) $x_{.i}$ which measures the ability of other species to grow in competition with i. General competitive ability measures the extent to which the competitive abilities of the various species can be estimated from $x_{i.} + x_{.i}$. Specific combining ability can be renamed specific competitive ability (s) and is a measure of deviations from the additive model. Reciprocal effects can be renamed within-pot effects (w) and are an overall measure of the variation due to $x_{ij} - x_{ji}$.

Since g and s effects are computed from sums ($x_{ij} + x_{ji}$) and w effects from differences ($x_{ij} - x_{ji}$), Williams (5) recommends partitioning the error term into two experimental errors, c_1 (computed from sums) and c_2 (computed from differences). c_1 is used to test g and s effects and c_2 to test w effects.

Because means and standard deviations for yield data are often proportional (5), the transformation $\log_e(x+1)$ was used.

Results and Discussion

For all analyses, g and w effects were highly significant (1% level) and constituted most of the competition variation (Table 2). The s effects were non-significant for weeks 2 and 3 and highly significant for both week 4 analyses. These analyses indicate that although there is wide variation in competitive abilities within pots, competitive relationships can be explained, for the most part, by a simple additive model. Significant deviations from this model did not occur until the 4th week and then were of minor importance.

Table 1. Arrangement of within-pot means (for each replication) for diallel analysis of competition data.

Species	Associate 1	2	.	.	.	p
1	–	x_{12}	.	.	.	x_{1p}
2	x_{21}	–	.	.	.	x_{2p}
.	.	.				
.	.	.				
p	x_{p1}	x_{p2}	.	.	.	–

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[3]For simplicity, $\bar{x}_{ij.}$, and $\bar{x}_{ji.}$ will be redesignated x_{ij} and x_{ji}, respectively.

Table 2. Mean squares from diallel analyses of transformed[z] height and dry weight values for sweet corn and 4 weed species.

Source of Variation	df	Height[y] 2 wk	3 wk	4 wk	Dry weight 4 wk
General competitive ability	4	7.53**	7.33**	4.95**	0.96**
Specific competitive ability	5	0.01	0.02	0.10**	0.03**
Error (c_1)	27	0.02	0.02	0.02	0.01
Within-pot effects	10	13.23**	14.97**	14.65**	4.31**
Error (c_2)	30	0.01	0.01	0.02	0.01

[z]Log_e (x+1).

[y]wk = weeks after seeding.

**Significant at 1% level.

Table 3. General competitive ability effects (g_i) and within-pot effects ($w_{ij} = -w_{ji}$) for transformed[z] heights and dry weights of sweet corn (SC) and 4 weed species.[y]

Species	w_{ij} BY	CG	SC	LQ	PW	g_i
			Height (2 weeks)[x]			
BY	–	0.73	−0.21	1.08	0.94	0.51
CG		–	−1.00	0.39	0.22	−0.21
SC			–	1.24	1.12	0.68
LQ				–	−0.18	−0.57
PW					–	−0.43
			Height (3 weeks)			
BY	–	0.60	−0.20	1.20	1.03	0.57
CG		–	−0.86	0.52	0.32	−0.03
SC			–	1.40	1.23	0.57
LQ				–	−0.19	−0.61
PW					–	−0.46
			Height (4 weeks)			
BY	–	0.53	−0.19	1.13	1.03	0.48
CG		–	−0.84	0.47	0.22	0.05
SC			–	1.44	1.26	0.39
LQ				–	−0.33	−0.54
PW					–	−0.38
			Dry weight (4 weeks)			
BY	–	0.40	−0.51	0.44	0.38	0.09
CG		–	−0.69	0.05	−0.14	−0.12
SC			–	0.71	0.65	0.31
LQ				–	−0.13	−0.16
PW					–	−0.13

[z]Log_e (x+1).

[y]Barnyardgrass (BY), large crabgrass (CG), lambsquarter (LQ), and redroot pigweed (PW).

[x]Weeks after seeding.

Week two g_i values indicate that barnyardgrass and sweet corn have comparable competitive abilities as do crabgrass, lambsquarter, and pigweed (Table 3). The latter 3 species appear to be substantially less competitive than barnyardgrass and sweet corn. Individual w effect values ($w_{ij} = -w_{ji}$) indicate that sweet corn and barnyardgrass have a substantial competitive advantage over the other species. Other w_{ij} effects are relatively small. Week 3 and 4 g_i and w_{ij} values for height are similar and reveal no noteworthy changes in competitive relationships except a small increase in the competitive ability of crabgrass.

Table 4. Specific competitive ability effects ($s_{ij} = s_{ji}$) for transformed heights and dry weights of sweet corn and 4 weed species after 4 weeks of growth.

Species	BY	CG	SC	LQ	PW
			Height		
BY	–	−0.06	0.19	−0.03	−0.08
CG		–	−0.07	0.04	0.13
SC			–	−0.02	−0.06
LQ				–	0.02
PW					–
			Dry weight		
BY	–	0.02	−0.08	0.05	0.04
CG		–	0.03	−0.05	0.03
SC			–	0.08	0.01
LQ				–	−0.03
PW					–

Dry weight g_i and w_{ij} values are generally consistent with week 4 height values except height values indicate a greater competitive ability for barnyardgrass and crabgrass than dry weight values.

s_{ij} (= s_{ji}) height values (Table 4) indicate that results are greater than expected for sweet corn-barnyardgrass and crabgrass-pigweed combinations. Other values are relatively small. There are no outstanding s_{ij} values for dry weight.

Analyses indicate that sweet corn had a competitive advantage over all other species. Barnyardgrass offered the most competition to sweet corn relative to the other species which offered much less competition to sweet corn and comparable competition to each other. These competitive relationships remained fairly constant throughout the experiment with perhaps a slight increase in the competitive ability of crabgrass over time. Changes in this simple competitive situation did not occur until the 4th week and entailed a slight increase in compatibility between sweet corn and barnyardgrass and between crabgrass and pigweed. Explanations for such phenomena range from allelopathy (3) to the occupation of different ecological niches (6).

Greenhouse-pot competition experiments yield only a rough approximation of competitive relationships in the field. Greenhouse factors such as root-growth restrictions, side lighting and artificial control of the environment can severely alter competitive relationships and extrapolation from the greenhouse to the field must be done with caution.

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