Interference of Three Annual Grasses with Grain Sorghum
(Sorghum bicolor)\(^1\)

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Abstract. Barnyardgrass, large crabgrass, and Texas panicum were evaluated in field experiments over 3 yr to measure their duration of interference and density on grain sorghum yield. When grain yield data were converted to a percentage of the weed-free control, linear regression predicted a 3.6% yield loss for each week of weed interference regardless of year or grass species. Grain sorghum grown in a narrow (61-cm) row spacing was affected little by full-season interference; however, in wide (91-cm) rows, interference increased as grass density increased. Data from the wide-row spacing were described by linear regression following conversion of grain yield to percentages and weed density to \(\log_{10}\). A separate nonlinear model also was derived which could predict the effect of weed density on grain sorghum yield. Nomenclature: Barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. \(^3\) ECHCG; large crabgrass, *Digitaria sanguinalis* (L.) Scop. \# DIGSA; Texas panicum, *Panicum texanum* Buckl. \# PANT; grain sorghum, *Sorghum bicolor* (L.) Moench. ‘Aco 4012R’ and ‘Funk G-623 GBR’.

Additional index words: Competition, duration, density, critical period, row spacing, ECHCG, DIGSA, PANT.

**INTRODUCTION**

Gramineae weeds are more common and/or troublesome than other weeds in grain sorghum in the southern region of the United States (6). The majority of the 13 reporting states listed the genera *Echinochloa*, *Digitaria*, *Panicum*, and *Sorghum* as important weeds in grain sorghum (6).

Cost-effective or economic weed control models capable of predicting weed-crop interference relationships have become an essential part of short- and long-term economic analysis (4). Guidelines were published in 1969 for economic weed control in grain sorghum using pigweed (*Amaranthus* spp.) interference data to determine the feasibility of economic control at various densities of pigweed in grain sorghum (13). One pigweed/30 cm\(^2\) in irrigated grain sorghum reduced grain yield approximately 48% (13). One barnyardgrass plant/m of crop row reduced grain sorghum yield nearly 10%, whereas 175 weeds/m of row reduced yield by 52% (11).

Cousens (4) reported that a nonlinear or rectangular hyperbola model was fitted successfully to experimental data from literature. In a later report, Cousens et al. (5) used a similar model to describe the relationship between population density and relative time of seedling emergence of wild oat (*Avena fatua* L.) and yield of barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.). By using data from the literature, they applied their model to describe these relationships and avoided two inherent errors caused by most models. First, their model avoided the prediction of yield loss when no weeds were present; and, second, their model did not predict yield increases from late-emerging weeds.

Interference from broadleaf weeds reduced grain sorghum yields more than interference from grass species or mixtures of broadleaf and grass weeds (8). Interference the first 2 weeks after crop emergence has not reduced grain sorghum yields, regardless of the weed studied (2, 8). Durations of weed growth beyond 2 weeks after grain sorghum emergence reduced yields depending on the weed species and environmental conditions (1, 7, 8). Yield reductions were primarily due to reduced seed/panicle (7, 8, 13), but reduced seed weight or panicles/plant were also important (1, 14).
Row spacing affects grain sorghum response to weed interference (3, 14, 15). Irrigated grain sorghum grown in 30-cm rows tolerated both large crabgrass and pigweed better than grain sorghum grown in 76-cm rows (15). This effect also was observed when both grass and broadleaf weeds interfered with grain sorghum grown without irrigation. Weeds interfered less with grain sorghum planted in 25- or 30-cm rows than grain sorghum planted in 101-cm rows in dryland experiments conducted in Texas (15) and Nebraska (3).

Insufficient information is available to develop models to predict grain sorghum yield responses due to weed interference. The objectives of this research were to measure the effects of interference by duration and by density of barnyardgrass, large crabgrass, and Texas panicum on grain sorghum yield.

MATERIALS AND METHODS

Grain sorghum was grown without irrigation on a Teller fine sandy loam (Udic Argiustoll) at the Agronomy Research Station near Perkins, OK, during 1979, 1980, and 1981. Fertility was adjusted annually by broadcast fertilizer applications according to state extension soil test recommendations. Greenbug-resistant ‘Acco 4012R’ grain sorghum was used in 1979, and ‘Funk G-623 GBR’ was used in 1980 and 1981.

A randomized complete block design with four replications was used in all experiments. Plot size was two rows by 10 m with a one-row border between plots. A new site at Perkins was selected for each experiment each year. Grain sorghum and weeds were planted May 31, 1979; June 5, 1980; and May 19, 1981. Time from planting to harvest was 111, 174, and 127 days, respectively. In 1980, excessive late-season rainfall delayed harvest until well after maturity.

Duration experiments. Intervals of weed interference were 0, 2, 4, 6, 8, 10, and 12 weeks from the date of planting. Grain sorghum was planted on a row spacing of 91 cm. Each year before use, germination tests were conducted on each grass species. Barnyardgrass, large crabgrass, and Texas panicum were sown annually by broadcasting approximately equal numbers of viable seed/plot. Weeds were removed from the plots by hand hoeing after each interference interval, and the plots were maintained weed free thereafter.

Grain sorghum yield was adjusted to 12% moisture and was analyzed by analysis of variance to determine if interactions among years or among grasses occurred. When possible, data were pooled. Grain sorghum plant height and head number were recorded and analyzed in 1980 and 1981. Yield data from weed-infested plots were converted to percentages of the weed-free control, were analyzed, and were regressed as described by Green et al. (9) and Mercer et al. (10). Linear and curvilinear regressions were computed to determine which described the data best.

Density and row-spacing experiments. Weed densities of 0, 4, 8, 16, 31, 62, 125, 250, and 500/10 m of crop row were established for each grass species and were allowed to interfere with grain sorghum throughout the season. Weed densities were established each year by overseeding and hand thinning. Seed of each grass species were planted 5 cm from the grain sorghum row immediately after planting the crop. Ten days after emergence, each plot contained only one species at a designated density.

An experiment in which grain sorghum was planted in 61-cm rows was adjacent to that planted in 91-cm rows in all 3 yr. The crop and weed densities within the row were constant; thus, the narrow-row plot contained higher crop and weed populations/hectare than the wide-row spacing.

Data from narrow-row and wide-row experiments were analyzed separately with analysis of variance and were tested for interactions among years and weed species. Data were pooled if significant interactions were absent. Yield data for experiments also were analyzed by linear and nonlinear regression procedures. Yield data from the wide-row spacing was pooled where appropriate, converted to percent yield reduction, and regressed versus log₁₀ of the weed density.

The model parameters used nonlinear components as suggested by Cousens et al. (5). The model derived to predict grain sorghum yield as affected by densities of individual weed species was \( \mu Y = \alpha e^{-\beta X} + \delta \) where \( \mu Y \) is the mean estimated grain sorghum yield in kilograms/hectare, \( \alpha \) is the estimated grain sorghum yield affected by a given weed species and density \( X \), \( e \) is the base of natural logarithms, \( \beta \) is the rate of yield loss from a single weed, and \( \delta \) is the asymptotic yield.

With this model, if weed density \( X \) is 0, then \( \alpha + \delta \) becomes the estimated weed-free yield. Likewise, when weed density \( X \) is large, the estimated yield is equal to \( \delta \). Williams and Hayes (16) used similar model parameters when describing the relationship between johnsongrass [Sorghum halepense (L.) Pers.] interference with soybean [Glycine max (L.) Merr.].
The PROC NLIN of SAS (12) was used to develop a predictive model for grain sorghum yield loss in the density experiments planted in 91-cm spacings.

RESULTS AND DISCUSSION

Duration experiments. Weed stands were not uniform among species each growing season. In 1979, density of barnyardgrass, large crabgrass, and Texas panicum was 93, 43, and 51 plants/m², respectively. Densities were higher the following years: 163, 413, and 181 plants/m² and 192, 347, and 277 plants/m² for those weed species in 1980 and 1981, respectively. No explanation is offered for those differences in stand density among years.

Grain sorghum plant height was not affected by interference intervals in 1980 (data not shown). In 1981, height decreased with longer durations of weed interference. After 12 weeks of interference, all grasses reduced crop height compared to grain sorghum grown weed free. However, crop height was apparently not a good indicator of weed interference.

Grain sorghum head counts varied; but like height, head production was not a good indicator of the impact of weed interference on grain sorghum production (data not shown). In 1981, interference for 8 and 12 weeks reduced grain sorghum head counts.

Interactions in grain sorghum yield data were observed among years; therefore, yield data were presented in separate years (Table 1). Data from 1979 and 1980 were pooled over grasses; but in 1981, a significant interaction among grasses was noted, and the data were not completely pooled. The variability in weed densities among species and years may have accounted for part of the statistical interactions observed.

Data which vary among years, experiments, and weed species are difficult to describe in a clear, concise manner using simple mean comparisons. To allow broader applications of such data, yield was converted into a percentage of the weed-free control plots and were reanalyzed using procedures similar to other interference research (9, 10). These converted data were suitable for developing a prediction model which would be useful at a producer level.

Following transformation to percentages, yield data did not interact among years or grasses. A single linear equation, \( \hat{Y} = 95.2 - 3.63X \) (R² = 0.95), predicted approximately a 3.6% yield loss with each additional week of weed interference, regardless of species. The conversion of yield data to percent yield reduction thus showed that a single equation could estimate the effects of these weeds on crop yield under a wide range of growing conditions, weed densities, and yield potential. Density and row spacing experiments. In narrow-row experiments, grain sorghum head number in 1980 showed a variable response to weed density (data not shown). Grain sorghum head production tended to increase with weed densities. Although this parameter was measured only in 1980 in the narrow-row studies, an increase in head number may be a mechanism by which the crop compensates for interference from grass weeds.

A pooled analysis of grain sorghum yield from narrow (61 cm) rows showed an interaction between years. During both years, decreasing yields did not correspond closely with increasing weed densities, and no distinct patterns were apparent (Table 2). Linear regression effectively described the relationship between weed density and reduced yields in 1979. However, in 1980 there was a poor coefficient of determination (R² = 0.06) with linear regression, and the slope did not differ significantly from zero. Likewise, a quadratic fit did not describe the relationship. Yields were not taken in 1981 because birds destroyed the harvestable grain during ripening.

Although both weed and crop populations were greater under narrow-row culture, greater grain sorghum populations would suggest that the canopy closed

Table 1. Effect of duration of annual grass interference on grain sorghum yield.

<table>
<thead>
<tr>
<th>Duration of interference after planting</th>
<th>Grasses combined</th>
<th>1979</th>
<th>1980</th>
<th>ECHCG</th>
<th>DIGSA</th>
<th>PANTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(weeks)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>2800</td>
<td>780</td>
<td>3250</td>
<td>3230</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2480</td>
<td>490</td>
<td>2850</td>
<td>2740</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>2380</td>
<td>490</td>
<td>2830</td>
<td>2630</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>2240</td>
<td>470</td>
<td>2660</td>
<td>2320</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1990</td>
<td>420</td>
<td>2400</td>
<td>2270</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>1870</td>
<td>380</td>
<td>2110</td>
<td>1740</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>1610</td>
<td>360</td>
<td>1820</td>
<td>840</td>
<td></td>
</tr>
</tbody>
</table>

Regression equations: b

Grasses combined (1979) \( \hat{Y} = 2750 - 92.5X^2 \) (R² = 0.98)
(1980) \( \hat{Y} = 650 - 27.7X^2 \) (R² = 0.73)

1981 a

ECHCG \( \hat{Y} = 3220 - 110.7X^2 \) (R² = 0.97)
DIGSA and PANTE \( \hat{Y} = 3270 - 170.2X^2 \) (R² = 0.90)

aInteractions among grasses in 1981 occurred; therefore, barnyardgrass (ECHCG) was analyzed and shown separately while large crabgrass (DIGSA) and Texas panicum (PANTE) showed no interaction and were pooled.

bAll regression values differed significantly from zero at the 0.05 probability level.

X is weeks of weed interference after planting.
Table 2. Effect of annual grass density on grain sorghum yield in 61- and 91-cm rows.

<table>
<thead>
<tr>
<th>Annual grass density (plants/10 m row)</th>
<th>61-cm rows</th>
<th>91-cm rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2610</td>
<td>1040</td>
</tr>
<tr>
<td>4</td>
<td>2630</td>
<td>930</td>
</tr>
<tr>
<td>8</td>
<td>2730</td>
<td>860</td>
</tr>
<tr>
<td>16</td>
<td>2760</td>
<td>910</td>
</tr>
<tr>
<td>31</td>
<td>2680</td>
<td>900</td>
</tr>
<tr>
<td>62</td>
<td>2580</td>
<td>780</td>
</tr>
<tr>
<td>125</td>
<td>2520</td>
<td>840</td>
</tr>
<tr>
<td>250</td>
<td>2410</td>
<td>860</td>
</tr>
<tr>
<td>500</td>
<td>2380</td>
<td>880</td>
</tr>
</tbody>
</table>

Regression equations:

\[ \hat{y} = 2600 - 0.7x^c \quad (R^2 = 0.73) \]
\[ \hat{y} = 2176 - 1.7x^c \quad (R^2 = 0.68) \]
\[ \hat{y} = 900 - 0.1x \quad (R^2 = 0.06) \]
\[ \hat{y} = 1335 - 1.3x \quad (R^2 = 0.61) \]
\[ \hat{y} = 3090 - 1.6x \quad (R^2 = 0.68) \]

(1979) and (1980)

No interactions among grasses were detected at the 0.05 probability level; thus, data were pooled over species.

Regression values differed significantly from zero at the 0.05 probability level in 1979, but not in 1980 with 61-cm rows.

X is weeks of weed interference after planting.

over the rows before the grass species became strongly established. These data suggest that narrow-row spacing may be an alternative grain sorghum production system with lower input from herbicides. However, additional equipment and increased seed costs must be considered as a limitation of this alternative system.

In 1980 and 1981, neither weed species nor densities reduced grain sorghum head number in wide-row (91 cm) experiments (data not shown). Neither weed species nor weed densities differed significantly, and there were no interactions among years when the data were pooled. Head number was not changed by increasing weed density in wide-row culture. These results are consistent with those of Feltner et al. (8) who reported that grain sorghum yield reductions from tall waterhemp [Amaranthus tuberculatus (Moq.) J. D. Sauer] interference were mediated by a reduced seed/panicle. Each year grain sorghum plant heights were erratic, and no clear relationship appeared to exist with weed density (data not shown).

Grain sorghum yield when grown in 91-cm rows steadily declined as annual grass density increased during each year of this research (Table 2). The three annual grasses behaved similarly within years and could be pooled. Data were adequately described by linear regression, and equations predicted a 1.7, 1.3, and 1.6 kg/ha yield decrease for each unit increase in weed density/10 m of row.

Following conversion of these yield data to percentages, each unit increase in weed density (expressed as \( \log_{10} 10 \) m of row was estimated to decrease yield 16, 19, and 11% for 1979, 1980, and 1981, respectively. The equations used for these estimates were \( \hat{y} = 103 - 16x \), \( \hat{y} = 102 - 19x \), and \( \hat{y} = 101 - 11x \) for 1979, 1980, and 1981, respectively. The coefficients of determination \( (R^2) \) were high, ranging from 0.96 to 0.99.

The parameter estimates used in the model effectively predicted grain sorghum yield in 91-cm rows.

Table 3. Parameter estimates for the suggested model applied to grain sorghum yield when grown in 91-cm rows.

<table>
<thead>
<tr>
<th>Species</th>
<th>Parameter estimates</th>
<th>Mean weed-free yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \alpha )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>ECHCG</td>
<td>1979</td>
<td>1038</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>693</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>743</td>
</tr>
<tr>
<td>DIGSA</td>
<td>1979</td>
<td>981</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>926</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>568</td>
</tr>
<tr>
<td>PANTE</td>
<td>1979</td>
<td>1064</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>606</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>1063</td>
</tr>
</tbody>
</table>

Pooled models:

\[ \mu \hat{y} = 745e^{-0.012x} + 1717 \]
\[ \mu \hat{y} = 800e^{-0.043x} + 1926 \]
\[ \mu \hat{y} = 820e^{-0.013x} + 1532 \]

Model fitted was \( \mu \hat{y} = \alpha e^{-\beta x} + \delta \) where \( \alpha \) is the estimated grain sorghum yield affected by a given weed species and density \( (X) \), \( \beta \) is the rate of yield loss by a single weed, and \( \delta \) is the asymptotic yield.

Barnyardgrass (ECHCG), large crabgrass (DIGSA), and Texas panicum (PANTE).

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compared to observed yield (Table 3). This model predicts yield loss from full-season interference rather than percent yield loss as described in previous models (4, 5). This model predicted yield at various weed densities under a range of conditions. A pooled model was derived for each weed species as a result of combining all years (Table 3).

Grain sorghum yield did not interact with years; therefore, data could be pooled among years (Table 3). From the pooled models, a comparison of the β parameters indicates the relative competitiveness of each grass species. On that basis, large crabgrass appears to have a threefold competitive advantage over the other two grasses when grown with grain sorghum in wide rows. Although a pooled model was statistically sound, the relative precision among years remains rather large.

In conclusion, as duration of interference with the three grass species increased, grain sorghum yield decreased. A 3.6% yield loss could be assessed with each week of weed interference. The effect of row spacing on grain sorghum yield was similar to previous reports (3, 14, 15).

Although a direct comparison of the effects of grain sorghum row spacing was not possible in these adjacent experiments, the grain sorghum grown in narrower rows apparently tolerates weed interference better than grain sorghum grown in wider rows. Linear regression functions fit data following conversion of yield data to percentages and weed density to \( \log_{10} \). In wide-row spacings, a model is suggested for predicting grain sorghum yield loss as the weed density of these three grasses increases. The regression of percentages and the suggested model using actual grain sorghum yields each add a degree of practicality that would allow their incorporation into a grain sorghum production operation.

LITERATURE CITED