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Effect of Defoliation at Different Stages on Grain Sorghum

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Summary
Loss of leaf area usually results in yield loss in grain crops, but the amount of yield loss varies with extent and timing of defoliation. Grass crops, such as corn and grain sorghum, are particularly sensitive to leaf area loss near the time of seed set because there is little opportunity for the plant to compensate. An experiment to quantify yield reductions associated with various levels of defoliation imposed at different stages of grain sorghum development was conducted at Manhattan, KS, in 2022. Target defoliations of 0, 33, 66, and 100% were imposed at 5-leaf, flag-leaf-appearance, half-bloom, and hard-dough stages. Defoliation of 5-leaf sorghum resulted in minimal yield loss unless the defoliation rate was 100%, which delayed heading and reduced head size and seed size. Leaf area losses of 50% or more at the hard dough stage caused yield reductions of only about 10–12%. Yield reductions were greatest when leaf area was lost at flag leaf appearance or half bloom. Leaf area loss of 60% and 100% caused yield losses of 25% and 75%, respectively. These yield losses were associated with different combinations of reductions in head size and seed size.

Introduction
Leaves are the primary source of energy for growth and grain filling in grain sorghum. Although dry matter is translocated from the stem to grain during grain filling, leaf area is required to deposit that dry matter in the stems. Hail damage tends to cause the greatest loss of leaf area on a field level and can be eligible for compensation via crop insurance. Usually, greater leaf area loss is associated with greater yield loss. However, that relationship changes as the sorghum crop develops. Leaf loss early in the season usually causes minimal yield loss because the lost leaf area is a relatively small fraction of the total. Additional leaves that emerge after the defoliation may support near normal seed set and grain fill. Leaf loss late in the season may cause minimal yield loss because grain fill has neared completion, and dry matter translocation from stems may somewhat compensate for the loss of new photosynthate. However, leaf area losses near the time of seed set are likely to cause the largest yield losses in sorghum and other grass crops because most of the leaf area has already emerged, and grain fill has just started. These relationships have been characterized in the past, but the response of modern sorghum hybrids in contemporary production systems is lacking. The objective of this experiment was to characterize the response of a modern grain sorghum hybrid to varying levels of leaf loss at different stages of crop development.

Procedures

Experiment Site and Agronomic Management

The experiment was located at Manhattan, KS, on a Kahola silt loam. Sorghum hybrid P84G62 was planted on June 6, 2022, at 75,000 seeds per acre using a White 9000 series planter with Precision Planting seed meters and 20|20 seed monitoring system. Fertilizer was applied before planting as a mix of 28% UAN and ammonium polyphosphate to supply 90 pounds of nitrogen and 55 pounds of P_2O_5 per acre. A residual herbicide mix was applied on May 17, and a burndown herbicide application was made immediately after planting. A mix of Huskie herbicide and Lambda Cy insecticides was applied on June 21 to control late-emerging Palmer amaranth and chinch bugs migrating from an adjacent wheat field, respectively. Plots were harvested on October 5–7 after reaching physiological maturity.

Treatments and Experimental Design

Treatments consisted of four levels of defoliation imposed at four developmental stages. The target defoliation levels were 0, 33, 66, and 100% and were imposed using a cordless hedge trimmer plus hand trimming the 100% treatment as needed. The sorghum stages when defoliations were imposed were S2 (5 leaves fully emerged), S4-flag (leaf visible in whorl), S6 (half bloom), and S8 (early hard dough). All treatments were arranged in a randomized complete block experimental design with five replications.

Data Collection and Analysis

Immediately after each defoliation, plants were clipped from a 3-foot section of row. Samples were refrigerated until processed to determine leaf area using a LiCor LI3100C area meter. Actual defoliation rate was calculated as the leaf area remaining immediately after defoliation as a percent of the 0% defoliation plots in each replication. Leaf area index (LAI) was calculated by dividing the sample leaf area by the sample soil surface area. Percent canopy coverage of the soil surface was estimated using the Canopeo app immediately after each defoliation. Days to half bloom was the number of days from planting until at least half the plants in the center two rows of each plot displayed anthers at least half-way down the head. The number of plants per acre was determined by counting all plants in the center two rows of each plot at sorghum stage S1 (3 leaves fully emerged) and dividing by the plot area in acres. The number of heads per plant was determined by dividing the number of heads per acre (counted at harvest) by the number of plants per acre. Seed size was determined by weighing 300 seeds. The number of seeds per head was calculated using the mass of grain, head number, and seed size. Grain yield was calculated by dividing the mass of grain by the harvest area and converted to bushels. Effect of defoliation was characterized by regressing days to half bloom, yield components, and yield on measured defoliation rate separately for each developmental stage. Pearson correlation coefficients were calculated for all combinations of variables using PROC CORR in SAS to characterize relationships between variables ($\alpha = 0.05$).

Results

Defoliation of S2 sorghum resulted in minimal yield loss unless the defoliation rate was 100%, which delayed heading and reduced head size and seed size. An accidental over-application of Aim and 2,4-D herbicides to the entire experiment to control surviving Palmer amaranth plants was made on June 27, the same day the S2 defoliations were imposed. Although most plants recovered rapidly, data from the S2 defoliations were eliminated from the summaries presented below because plant recovery after defoliation was likely affected by the herbicide application.

Effect of Defoliation on Remaining Leaf Area and Bloom Date

Increasing rates of defoliation were strongly negatively correlated with leaf number, LAI, canopy coverage, and S9 LAI over all developmental stages and within each developmental stage (Table 1). Greater defoliation rates increased days to half bloom only at S4 (Table 1, Figure 1).

Effect of Defoliation on Yield Components and Yield

Defoliation affected yield components differently depending on the developmental stage when the defoliation was imposed. Plants per acre were not affected by defoliation rate (Figure 2) and were strongly correlated only with heads per plant (Table 1). Defoliation had a minimal effect on heads per plant (Figure 3). Head size decreased with greater defoliation (Figure 4), with the largest decreases when defoliated at S4 and the smallest when defoliated at S8 (Table 1). Seed size decreased only at high rates of defoliation (Figure 5) and was reduced the most when defoliated at S6 and the least when defoliated at S8 (Table 1). Yield was reduced by 60 to 80% with high rates of defoliation at developmental stages S4 and S6, but yield reduction was minimal with defoliation at S8 (Figure 6, Table 1).

Relationships Among Sorghum Response Variables

Defoliation had strong, negative correlations with the various measures of leaf area over defoliations at all developmental stages and at each stage (Table 1). Defoliations imposed at S4 and S6 also had strong, negative correlations with head size, seed size, and yield. However, defoliation at S8 was not strongly correlated with any yield component or yield.

Conclusion

Defoliation tended to reduce yield, but the degree of yield reduction varied with timing and extent of defoliation. The greatest yield reductions resulted from defoliations at S4 and S6, which reduced both head size and seed size. Yield reductions were minimal with defoliations at S8 and were associated with reductions in seed size.

Acknowledgments

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Table 1. Pearson correlation coefficients for defoliation of grain sorghum at Manhattan, KS, 2022

	Defoliation	Days bloom	Plants/ acre	Heads/ plant	Seeds/ head	Seed size	No. leaves	LAI[1]	Canopy[2]	S9 LAI[1]	Yield
		↓ stage 4 (flag leaf appearance, upper right) ↓									
Defoliation		**0.75**	0.07	0.08	**-0.93**	**-0.48**	**-0.87**	**-0.99**	**-0.95**	**-0.87**	**-0.90**
Days bloom	0.34		-0.09	0.21	**-0.72**	-0.17	**-0.68**	**-0.72**	**-0.75**	**-0.61**	**-0.62**
Plants/acre	0.01	**-0.33**		**-0.78**	-0.18	-0.10	-0.22	-0.10	-0.03	-0.18	-0.18
Heads/plant	0.12	**0.38**	**-0.66**		0.05	0.11	0.15	-0.01	-0.11	0.14	0.14
Seeds/head	**-0.66**	**-0.46**	-0.12	-0.16		**0.46**	**0.90**	**0.91**	**0.92**	**0.86**	**0.95**
Seed size	**-0.56**	-0.07	0.01	0.02	**0.47**		**0.66**	**0.52**	**0.57**	**0.46**	**0.71**
No. leaves	**-0.80**	**-0.29**	-0.12	-0.14	**0.77**	**0.61**		**0.88**	**0.89**	**0.77**	**0.93**
LAI	**-0.97**	**-0.32**	0.00	-0.13	**0.64**	**0.56**	**0.79**		**0.94**	**0.86**	**0.91**
Canopeo	**-0.81**	**-0.28**	0.01	-0.04	**0.50**	**0.54**	**0.61**	**0.73**		**0.86**	**0.91**
S9 LAI	**-0.93**	-0.23	-0.01	-0.06	**0.53**	**0.57**	**0.69**	**0.94**	**0.75**		**0.85**
Yield	**-0.71**	**-0.36**	-0.08	0.00	**0.90**	**0.78**	**0.78**	**0.69**	**0.59**	**0.63**	
		↑ across all stages (lower left) ↑									
		↓ stage 8 (hard dough, upper right) ↓									
Defoliation		0.21	-0.05	0.33	-0.39	-0.26	**-0.77**	**-0.97**	**-0.92**	**-0.97**	-0.31
Days bloom	-0.07		**-0.70**	**0.70**	-0.13	-0.30	-0.16	-0.17	-0.17	-0.17	-0.15
Plants/acre	0.01	-0.33		**-0.65**	-0.24	0.24	-0.06	0.07	0.08	0.07	-0.01
Heads/plant	-0.22	0.14	**-0.66**		-0.28	-0.15	-0.33	-0.31	-0.34	-0.31	-0.01
Seeds/head	**-0.69**	-0.07	0.07	-0.13		0.20	0.39	0.30	0.34	0.30	**0.66**
Seed size	**-0.83**	0.03	-0.09	0.13	**0.81**		0.15	0.27	0.36	0.27	**0.78**
No. leaves	**-0.88**	0.13	-0.07	0.10	**0.83**	**0.94**		**0.73**	**0.76**	**0.73**	0.20
LAI	**-1.00**	0.08	0.00	0.21	**0.69**	**0.83**	**0.88**		**0.87**	**1.00**	0.27
Canopeo	**-0.92**	0.13	-0.01	0.11	**0.80**	**0.90**	**0.95**	**0.92**		**0.87**	0.34
S9 LAI	**-1.00**	0.08	0.00	0.21	**0.69**	**0.83**	**0.88**	**1.00**	**0.92**		0.27
Yield	**-0.83**	-0.05	-0.02	0.09	**0.93**	**0.95**	**0.92**	**0.83**	**0.89**	**0.83**	
		↑ stage 6 (half bloom, lower left) ↑									

[1]LAI = leaf area index. S9 LAI = LAI at sorghum developmental stage 9, physiological maturity.
[2]Estimate of % ground cover using the Canopeo App.
Bold values indicate 95% confidence of significant correlation.

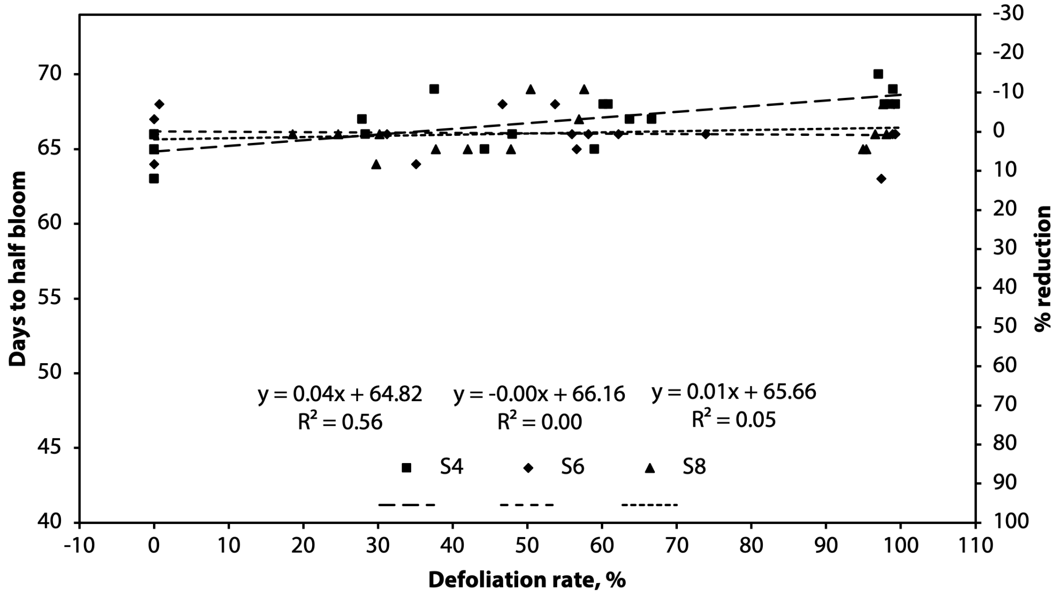

Figure 1. Effect of defoliation at three grain sorghum developmental stages on days to half bloom at Manhattan, KS, in 2022.

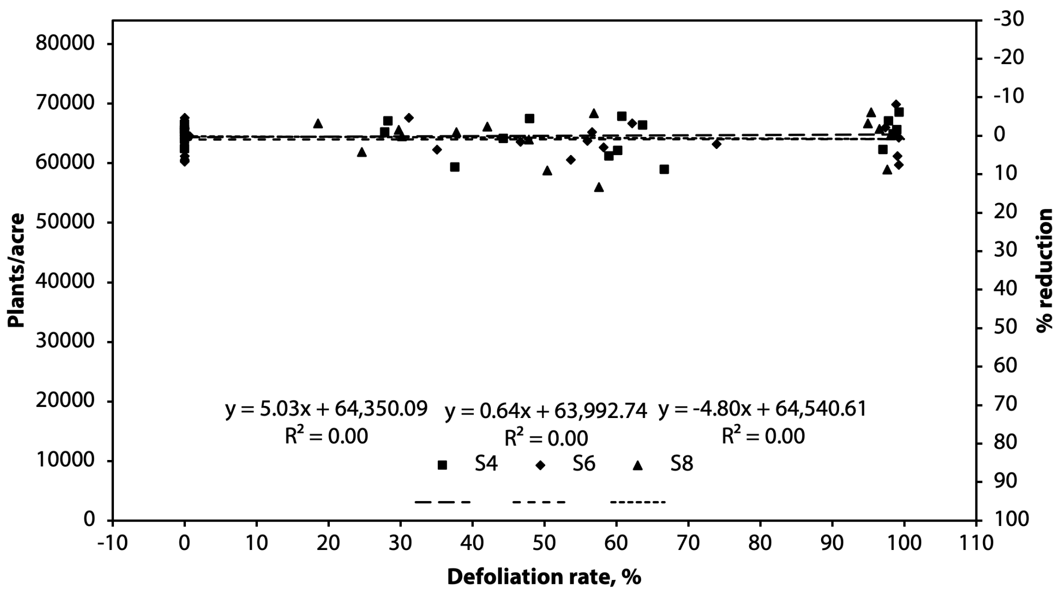

Figure 2. Effect of defoliation at three grain sorghum developmental stages on plant density at Manhattan, KS, in 2022.

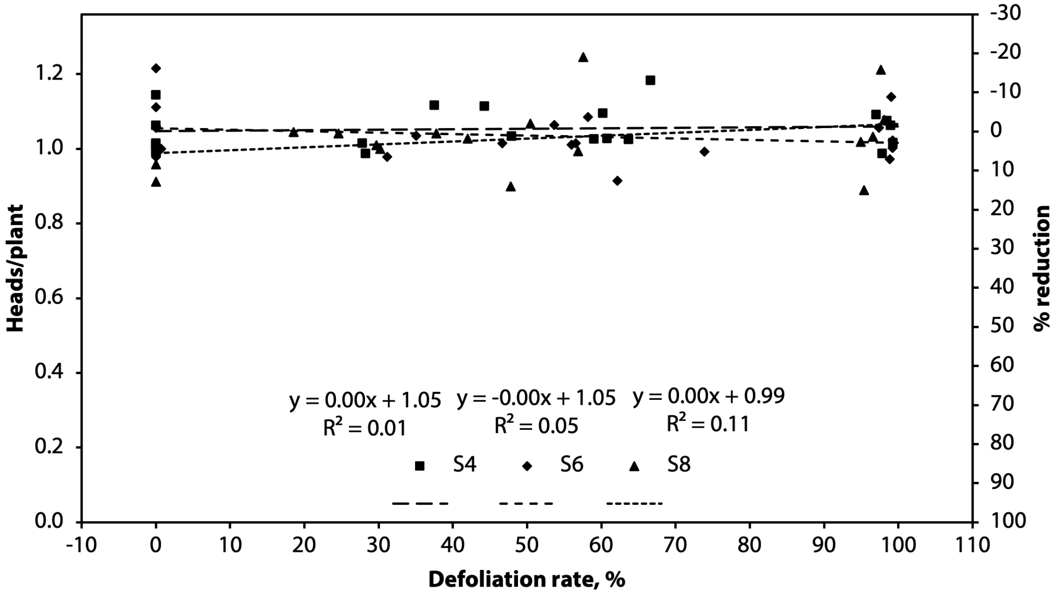

Figure 3. Effect of defoliation at three grain sorghum developmental stages on number of heads per plant at Manhattan, KS, in 2022.

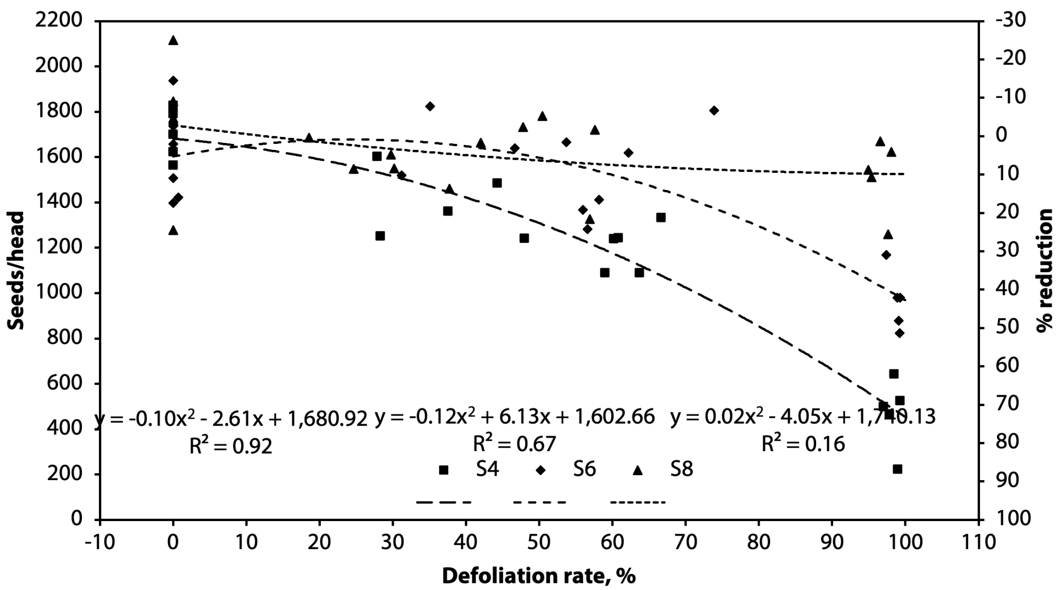

Figure 4. Effect of defoliation at three grain sorghum developmental stages on number of seeds per head at Manhattan, KS, in 2022.

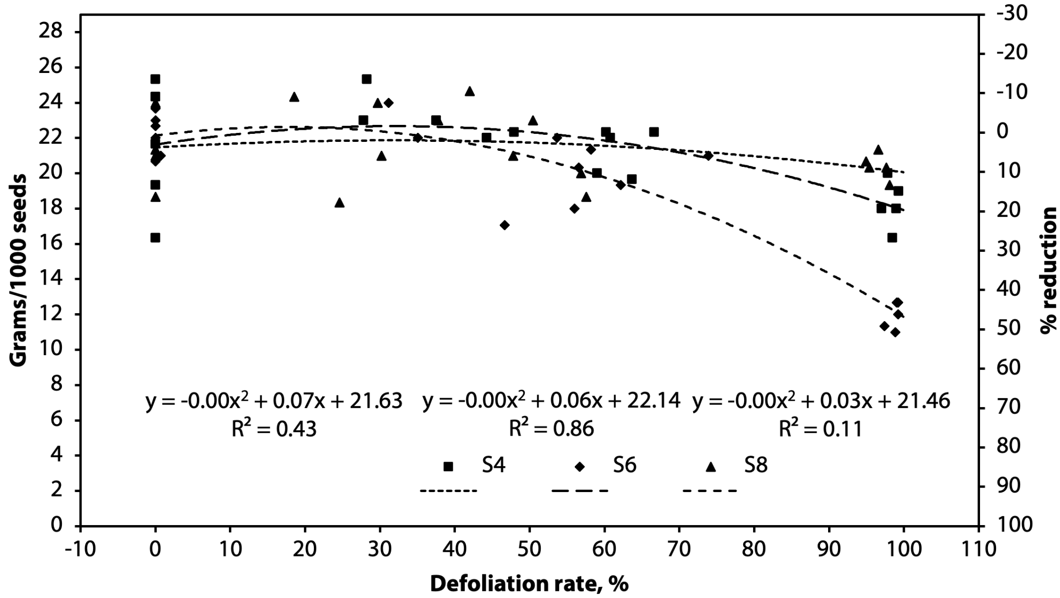

Figure 5. Effect of defoliation at three grain sorghum developmental stages on seed size at Manhattan, KS, in 2022.

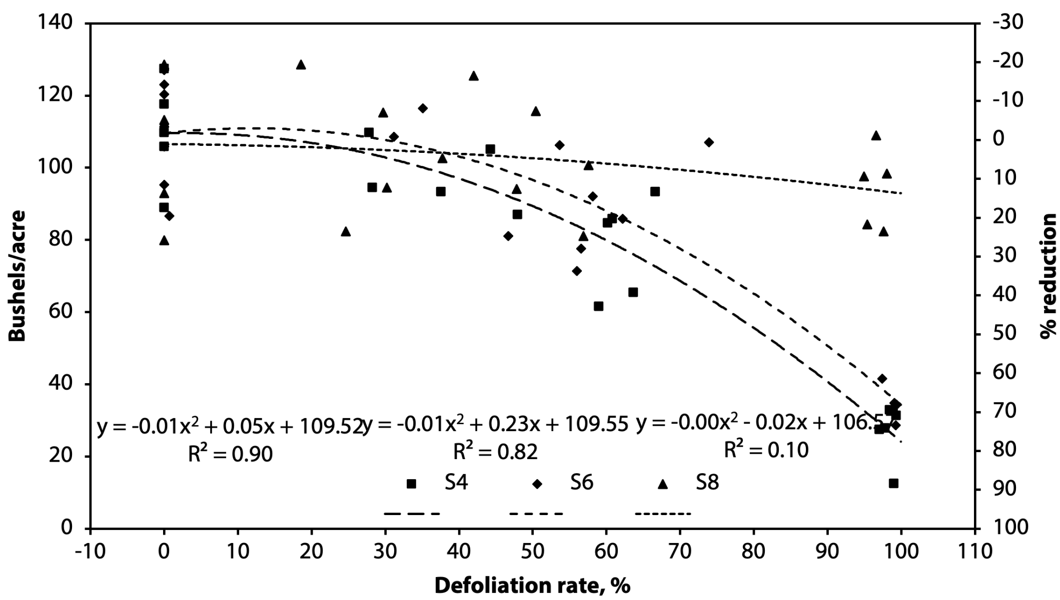

Figure 6. Effect of defoliation at three grain sorghum developmental stages on grain yield at Manhattan, KS, in 2022.