Effect of Defoliation at Different Stages on Grain Sorghum Yield and Yield Components in 2024

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Summary
A third year of 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 2024. 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 also delayed heading. Yield reductions were greatest when leaf area was lost at flag leaf appearance or half bloom. Leaf area loss of 60% or greater at these stages caused yield losses of 30% to 70%. Leaf area losses approaching 100% at the early hard dough stage caused yield reductions approaching 30%. Yield losses were associated with different combinations of reductions in head size and seed size depending on timing of leaf loss.

Introduction
Although dry matter is translocated from the stem to grain during grain filling, leaves are the primary source of energy for growth and grain filling in grain sorghum. Of several possible causes, 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. Leaves that emerge after 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 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 because most of the leaf area has already emerged, and little grain fill has occurred. These responses for modern sorghum hybrids in contemporary production systems have not been characterized. 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 soil. Sorghum hybrid P84P72 was planted on June 10, 2024, at 75,000 seeds per acre using a White

9000 series planter with Precision Planting seed meters and a 20|20 seed monitoring system. Fertilizer was applied before planting as a mix of 28% UAN and ammonium polyphosphate to supply 150 pounds of nitrogen and 55 pounds of P_2O_5 per acre. A mix of burndown and residual herbicides was applied before crop emergence on May 10. Plots were harvested on October 16–19 after reaching physiological maturity.

Treatments and Experimental Design

Treatments consisted of four levels of defoliation imposed at four developmental stages. Target defoliation levels of 0, 33, 66, and 100% were imposed using a hedge trimmer plus hand trimming the 100% treatment as needed. The sorghum stages when defoliations were imposed were 5 leaves fully emerged (S2), flag leaf visible in whorl (S4), half bloom (S6), and early hard dough (S8). 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. Leaf area was determined using a LiCor LI3100C area meter. Actual defoliation rate was calculated as the leaf area remaining as a percent of the 0% defoliation plot in each replication. Leaf area index (LAI) was calculated by dividing the sample leaf area by the sample soil surface area. 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 heads per plant was determined by dividing the number of heads by the number of plants counted in the harvest area. 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. The effect of defoliation was characterized by regressing the response parameters on measured defoliation rate separately for each developmental stage. Pearson correlation coefficients were calculated for all combinations of variables to characterize relationships among variables.

Results

Growing Season Conditions

Growing conditions were generally favorable for sorghum growth during the 2024 growing season (Figure 1). Temperatures were close to normal until planting. Although temperatures averaged near normal for the rest of the growing season, they tended to swing from above to below normal every several days. Cumulative precipitation was above normal until late August. Although there was minimal precipitation during the grain filling period, no visual drought response symptoms were observed.

Effect of Defoliation on Remaining Leaf Area, Bloom Date, and Plant Height

Increasing rates of defoliation were significantly negatively correlated with LAI across all developmental stages and within each stage when defoliation was imposed (Table 1). Increasing rates of defoliation at S2 and S4 delayed half bloom, defoliations imposed at S6 and S8 had no effect on half bloom (Table 1, Figure 2). Plant height was not influenced by defoliation at S2, S6, and S8, but was reduced as S4 defoliation rate increased (Table 1, Figure 3).

Effect of Defoliation on Yield Components and Yield

Defoliation affected yield components differently depending on the developmental stage when the defoliation was imposed. Plant density differences due to defoliation were substantially less than differences due to non-uniform stands (Figure 4), which were not large enough to influence yield (Table 1). The number of heads per plant responded minimally to defoliation at any growth stage (Table 1). As with plant density, differences in heads per plant due to defoliation were within the range of variation across all rates of defoliation imposed at any growth stage (Figure 5). The lack of tillering response might be explained in part by the late planting date because sorghum tends to produce fewer productive tillers when temperatures are warmer during early vegetative stages. Head size was the yield component most responsive to defoliation, with fewer seeds per head with greater defoliation rates at S4, S6, and S8 (Table 1, Figure 6), although the decrease in head size for defoliations imposed at S8 were minimal. Defoliation rates approaching 100% at S4 and S6 resulted in head size reductions of 50% and 35%, respectively. Increasing rates of defoliation at S4, S6, and S8 were strongly associated with decreased seed size (Table 1). Seed size was reduced by 10% to 20% with maximum defoliation imposed at S4 and S8 but was reduced by 50% with maximum defoliation at S6 (Figure 7). Increasing rates of defoliation were strongly negatively correlated with grain yield regardless of when the defoliation was imposed (Table 1). Complete defoliation at S6 resulted in the most severe yield reduction of almost 70%, followed by S4, which had a yield reduction of 40% to 60% (Figure 8). Only the most severe defoliation at S2 affected yield, with yield reductions between 10% and 20%. The 10% reduction in head size and 20% reduction in seed size resulting from 100% defoliation at S8 translated into a nearly 30% reduction in yield.

Relationships Among Sorghum Response Variables

Plant density was strongly negatively correlated with number of heads per plant but was not related to differences in yield (Table 1), illustrating sorghum's ability to compensate for non-uniform stands. The number of heads per plant was unrelated to other yield components. It was positively correlated with yield only when defoliations were imposed at S4. Correlations of days to half bloom with plant height and LAI when defoliations were imposed at S2 and S4 were likely mediated by defoliation rate.

Head size and seed size displayed no correlation with other parameters with defoliations imposed at S2. However, at S4, head size and seed size were correlated with plant height, LAI, and yield. At S6 and S8, head size and seed size were strongly correlated with each other and with LAI, and yield.

Yield was strongly correlated with LAI at the time of defoliation for all defoliation timings, but relationships between yield and yield components varied with timing of defoliation (Table 1). For defoliations at S2 and S4, yield was negatively correlated with days to bloom. Yield had strong correlations with heads per plant, head size, and seed size with defoliation at S4, but only head size and seed size were strongly correlated with yield when defoliations were imposed at S6 or S8.

Conclusion

Defoliation tended to reduce yield, but the degree of yield reduction varied with timing and extent of defoliation. Light to moderate defoliations at S2 resulted in minimal yield reduction, likely because the plants could add leaf area and additional productive heads when defoliated at this stage. Severe defoliation at S2 delayed heading and reduced yield by 10% to 20%. Yield reductions of 30% from severe defoliation at S8 were associated with reductions in seed size and with reductions in head size, likely due to kernel abortion. Severe defoliations at S4 and S6 resulted in smaller heads and seeds that reduced yield by 60% to 70%.

Acknowledgments

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Table 1. Pearson correlation coefficients for defoliation of grain sorghum at Manhattan, KS, 2024; bold values indicate 95% confidence in significant correlation

	Defoliation	Days bloom	Plant height	Plant density	Heads/ plant	Head size	Seed size	LAI[1]	Yield
				↓ stage 4 (flag leaf appearance, upper right) ↓					
Defoliation		**0.65**	**-0.65**	0.03	-0.00	**-0.82**	**-0.53**	**-1.00**	**-0.86**
Days bloom	**0.97**		**-0.56**	-0.16	0.02	-0.41	-0.36	**-0.65**	**-0.59**
Plant height	-0.19	-0.16		0.08	-0.09	**0.50**	0.13	**0.65**	**0.59**
Plant density	-0.19	-0.24	0.36		**-0.82**	-0.36	-0.05	-0.03	-0.22
Heads/plant	0.04	0.10	-0.19	**-0.66**		0.24	0.11	0.00	**0.23**
Head size	-0.01	0.10	0.35	-0.09	-0.04		0.39	**0.82**	**0.88**
Seed size	-0.41	-0.39	0.10	-0.04	-0.25	-0.12		**0.52**	**0.57**
LAI	**-1.00**	**-0.96**	0.17	0.18	-0.03	0.00	0.39		**0.86**
Yield	**-0.60**	**-0.56**	0.24	0.03	0.41	0.13	0.03	**0.57**	
				↑ stage 2 (five leaves emerged, lower left) ↑					
				↓ stage 8 (hard dough, upper right) ↓					
Defoliation		-0.29	-0.10	0.26	-0.13	**-0.68**	**-0.87**	**-1.00**	**-0.87**
Days bloom	-0.08		0.14	0.33	-0.28	0.20	0.06	0.27	0.16
Plant height	-0.18	-0.41		0.04	0.06	-0.14	0.07	0.10	0.14
Plant density	0.23	-0.19	-0.18		**-0.79**	**-0.55**	-0.41	-0.29	-0.27
Heads/plant	-0.14	0.07	-0.30	**-0.76**		0.39	0.25	0.14	0.32
Head size	**-0.78**	-0.01	0.39	-0.25	0.08		**0.51**	**0.70**	**0.67**
Seed size	**-0.90**	-0.03	0.30	-0.30	0.15	**0.76**		**0.88**	**0.84**
LAI	**-0.99**	0.12	0.13	-0.15	0.07	**0.75**	**0.89**		**0.88**
Yield	**-0.90**	-0.04	0.24	-0.22	0.17	**0.85**	**0.95**	**0.89**	
				↑ stage 6 (half bloom, lower left) ↑					
				↓ over all stages (upper right) ↓					
Defoliation		**0.41**	**-0.30**	0.05	-0.02	**-0.54**	**-0.61**	**-0.71**	**-0.73**
Days bloom			**-0.25**	**-0.23**	0.15	0.06	-0.02	**-0.42**	-0.05
Plant height				0.12	**-0.24**	**0.42**	0.16	**0.25**	**0.36**
Plant density					**-0.73**	**-0.25**	-0.18	0.02	-0.18
Heads/plant						0.04	0.08	-0.05	0.15
Head size							**0.44**	**0.31**	0.79
Seed size								**0.49**	**0.76**
LAI									**0.48**

[1]LAI = leaf area index.

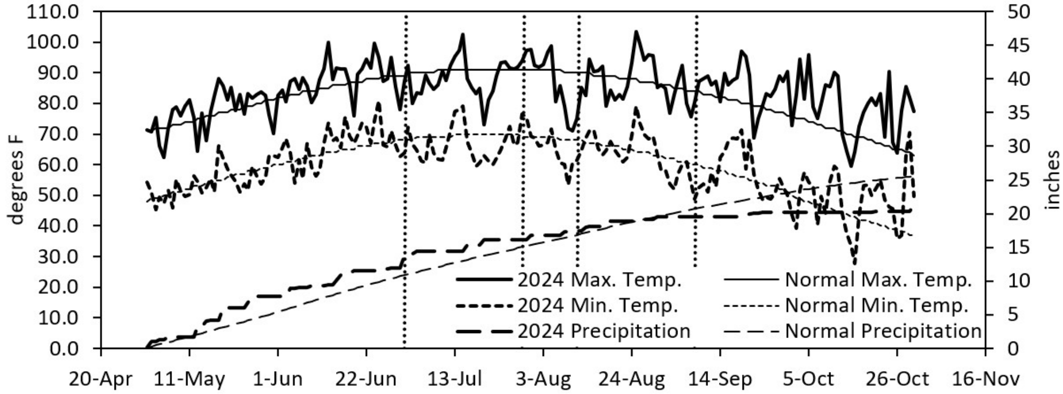

Figure 1. Daily maximum and minimum temperatures and cumulative precipitation for 2024 and 30-year normals for Manhattan, KS. Vertical dotted lines represent defoliation events.

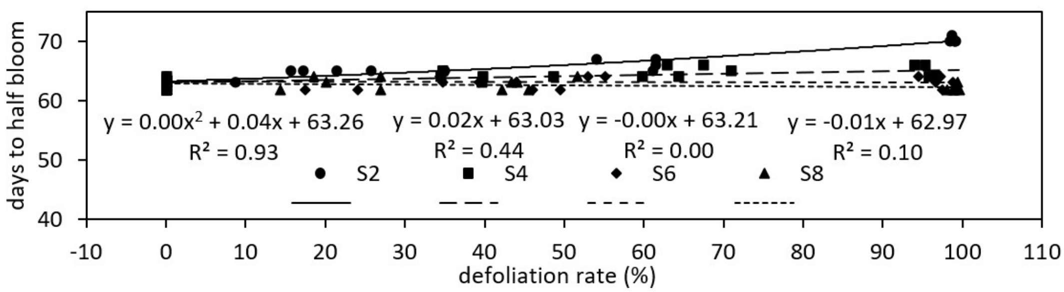

Figure 2. Effect of defoliation at four grain sorghum developmental stages on days to half bloom at Manhattan, KS, in 2024.

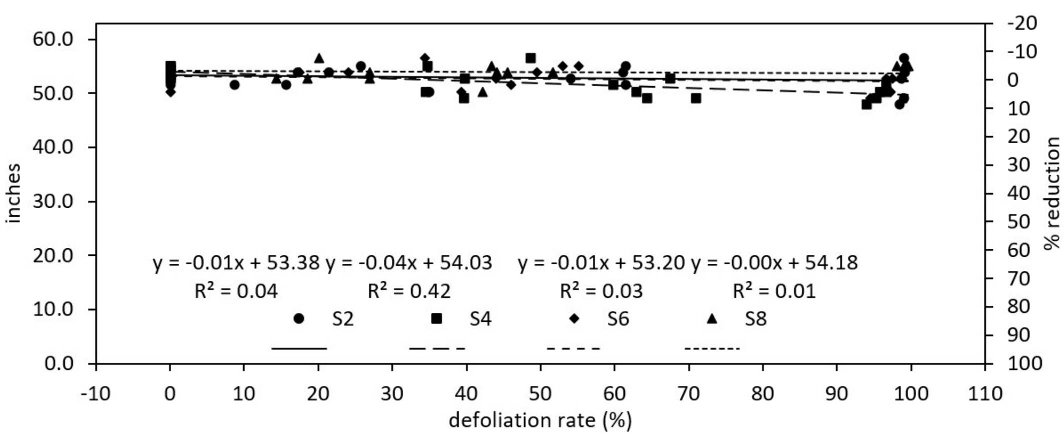

Figure 3. Effect of defoliation at four grain sorghum developmental stages on plant height at Manhattan, KS, in 2024.

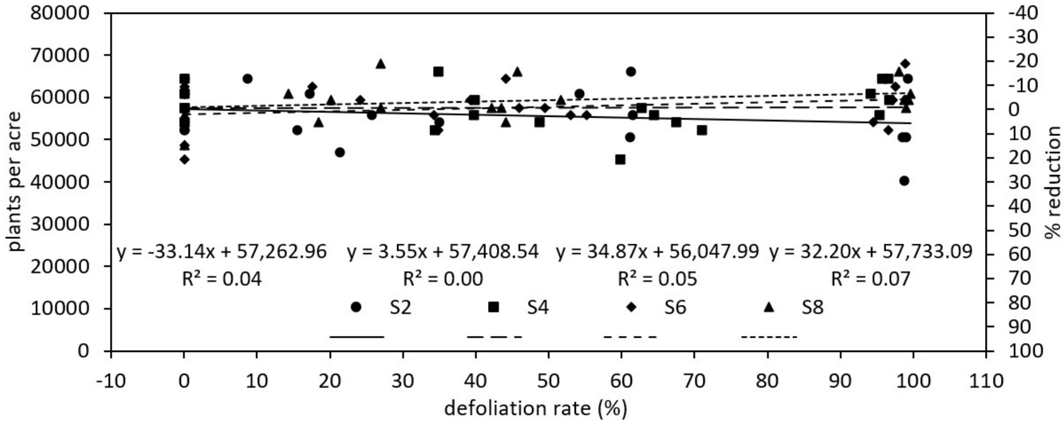

Figure 4. Effect of defoliation at four grain sorghum developmental stages on plant density at Manhattan, KS, in 2024.

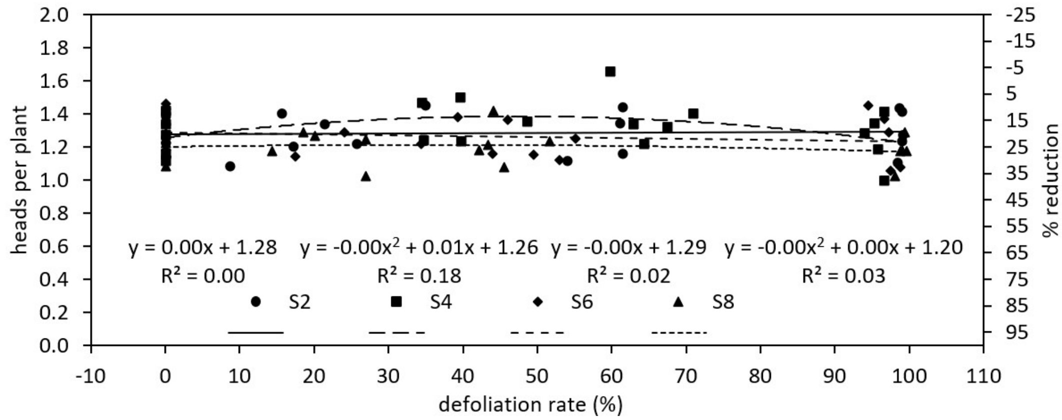

Figure 5. Effect of defoliation at four grain sorghum developmental stages on number of heads per plant at Manhattan, KS, in 2024.

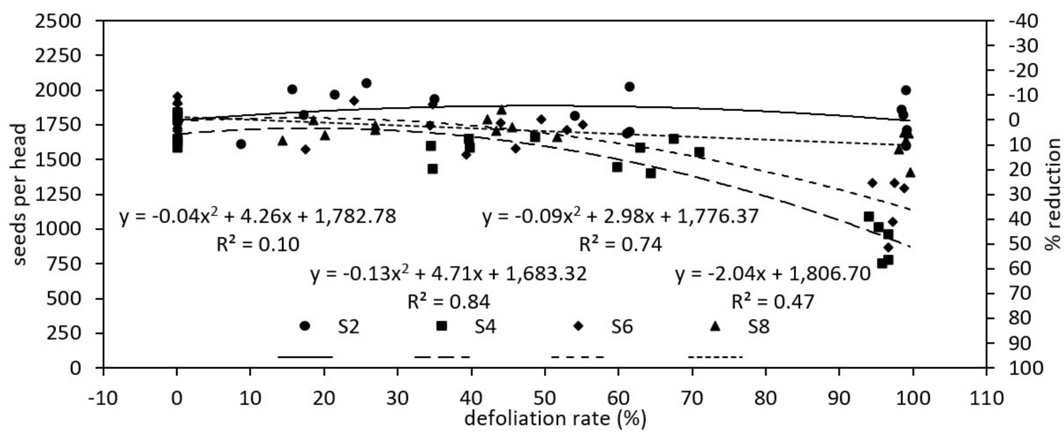

Figure 6. Effect of defoliation at four grain sorghum developmental stages on head size at Manhattan, KS, in 2024.

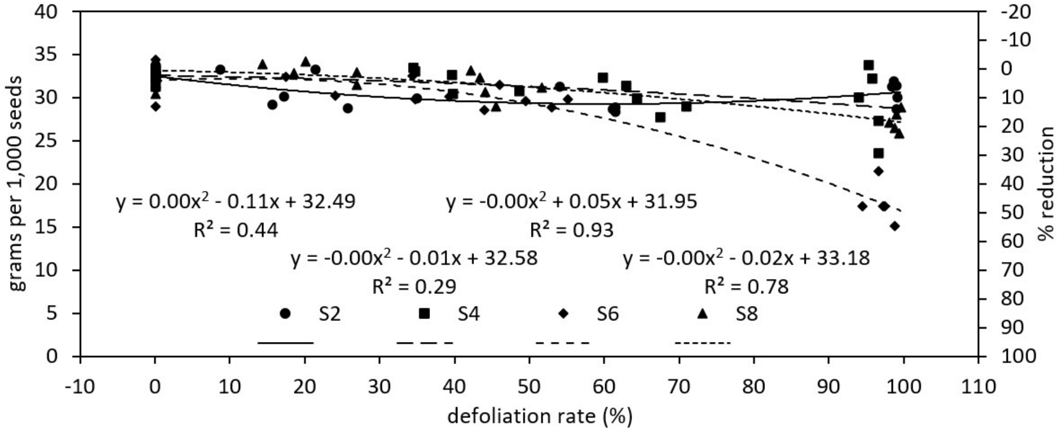

Figure 7. Effect of defoliation at four grain sorghum developmental stages on seed size at Manhattan, KS, in 2024.

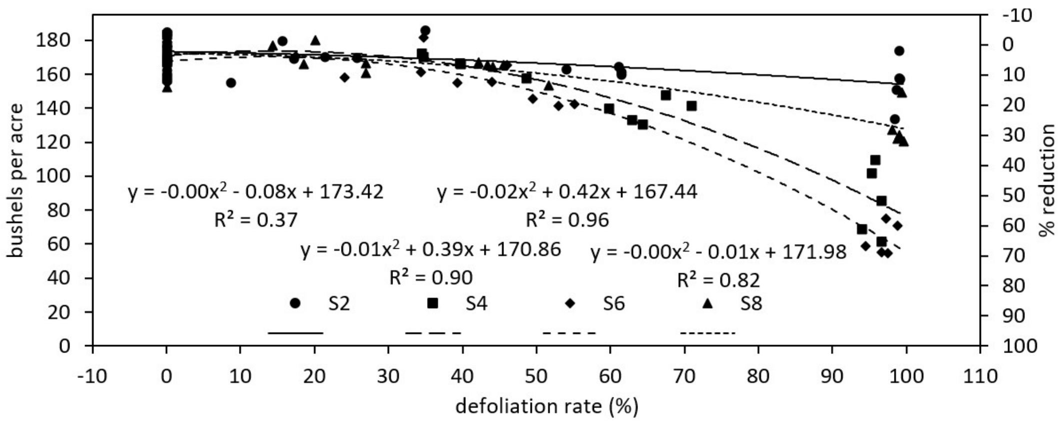

Figure 8. Effect of defoliation at four grain sorghum developmental stages on grain yield at Manhattan, KS, in 2024.