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Residual Herbicide Programs With Multiple Sites-of-action Improved Weed Control in Grain Sorghum

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Summary

A strong preemergence herbicide program is an essential best management practice for multiple herbicide-resistant weeds. Palmer amaranth is a prolific seed producer that has evolved resistance to 6 herbicide sites-of-action in Kansas. The objective of this study was i) to evaluate the effectiveness and crop safety of residual herbicide programs with single and multiple sites-of-action used for weed control in no-till dryland grain sorghum production systems of western Kansas and ii) the impact of lowering the rate of Callisto in mixture with Dual II Magnum on weed control in no-till dryland grain sorghum production systems of western Kansas. Results showed that the preemergence herbicide treatments controlled Palmer amaranth (96-100%), puncturevine (93-100%), and large crabgrass (96-100%) 22 days after application. However, control of these weeds decreased at 43 days after treatment, with atrazine providing the least control (63-70%) compared to other herbicide combinations, including FulTime NXT, Calibra, atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto (83-100%). Sorghum injury ranged from 1.3% to 17% 15 days after treatment, but sorghum recovered with injury levels of 7% or less at 43 days after treatment. The Dual II Magnum + Callisto combinations resulted in higher yields (92-94 bu/a) compared to the untreated control (69 bu/a). The results suggest that the herbicides evaluated can be safely applied to sorghum for weed control under favorable environmental conditions. Higher rates of Callisto in combination with Dual II Magnum did not offer additional weed control benefits compared to the lower rates used in this trial. Regardless of application rates, herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. Therefore, these herbicide programs can help minimize Palmer amaranth escapes and prevent the replenishment of the soil seedbank.

Grain sorghum is a weak competitor with most weeds because it grows slowly, particularly during the early stage of growth (Thompson et al. 2019). This results in ample opportunity for weeds to occupy space, compete with the crop, and reduce yields. Research has shown that even light weed infestations in the early growing season will reduce yields significantly. Weed control options in grain sorghum are more limited compared to corn, cotton, and soybeans. Grain sorghum is not tolerant to many widely used grass and broadleaf herbicides and can sometimes suffer injury from herbicides that are labeled for use in sorghum. In addition, the effectiveness of many herbicides has been reduced due to the development of resistant weeds (Thompson et al. 2019).

One of the most troublesome weeds in Kansas grain sorghum production is Palmer amaranth due to its ability to develop resistance to multiple herbicides (Heap, 2025). It has evolved metabolic resistance to six different herbicide sites-of-action within the state and is known for its high seed production, which allows it to rapidly replenish the soil seedbank. Therefore, effective management of herbicide-resistant weeds such as Palmer amaranth in grain sorghum requires the implementation of a strong residual herbicide program. In fact, previous research on the emergence patterns of glyphosate-resistant Palmer amaranth, using a resistance-simulation model, emphasized the importance of residual herbicides in ensuring season-long weed suppression and reducing seed production. Moreover, keeping crop fields free of weeds, especially in conservation-tillage systems where preplant tillage is not an option, requires the application of residual herbicides. The objectives of this study were to evaluate the effectiveness of weed control and crop tolerance in no-till dryland grain sorghum production systems of western Kansas resulted from i) residual herbicide programs with single and multiple sites-of-action and ii) the impact of lowering the rate of Callisto in mixture with Dual II Magnum herbicide programs for weed control.

Procedures

This study was conducted during the 2024 growing season at K-State Agricultural Research Center near Hays, Kansas, on a soil classified as a Harney silt loam, with a slope range of 0 - 1% (USDA-SCS, 1969) and a pH of 6.4. Particle size analysis revealed that the soil consisted of 8% sand, 54% silt, and 38% clay. The field site had a natural infestation of Palmer amaranth (*Amaranthus palmeri*), puncturevine (*Tribulus terrestris*), and large crabgrass (*Digitaria sanguinalis*). The experiment was implemented in a no-till system. The study was arranged in a randomized complete block design with 4 replications. Plot size was 10 feet by 27 feet. In total, 12 pre-emergence herbicide programs were evaluated (Table 1).

All the pre-emergence herbicides were applied on the day of grain sorghum planting. A CO_2-pressurized backpack sprayer with TeeJet AIXR11002 nozzles (Spraying Systems Co., Glendale Heights, IL) calibrated to deliver 15 gpa spray volume, at 3 mph, was used to spray the pre-emergence herbicide treatments. Weed control was assessed visually at 22 and 43 days after treatment, while crop injury was assessed visually at 15, 29, and 43 days after preemergence herbicide application on a scale of 0% to 100% (where 0% is no injury and 100% is complete death of the plant). K-State Research and Extension recommendations for agronomic practices were followed. Yield was determined at physiological maturity by harvesting the middle two rows of each plot, and yields from each treatment were converted to bushel/a at 13% moisture content.

Results and Discussion

Palmer amaranth control

All the pre-emergence herbicide programs suppressed Palmer amaranth compared to the non-treated control throughout the period of observation. Palmer amaranth control was similar among the pre-emergence herbicide treatments and ranged from 96% to 100% at 22 days after treatment (data not shown). However, as the season progressed, Palmer amaranth control with atrazine 43 days after treatment (63%) was lower relative to other pre-emergence herbicide treatments (83% to 99%) (Figure 1). Regardless of application rates, the mixtures of Dual II Magnum + Callisto provided greater control of Palmer amaranth (91% to 99%) compared with sole application of atrazine, Dual II Magnum, Outlook, or Warrant (63% to 88%). Palmer amaranth control with mixtures of Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a showed no differences, indicating that higher rates of Callisto in combination with Dual II Magnum did not offer additional weed control benefits compared to the lower rates used in this study. Consequently, using higher rates may increase the cost of weed control without providing added effectiveness.

This study demonstrates that herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. Palmer amaranth in Kansas has developed metabolic resistance to six herbicide sites-of-action (Heap 2025). Additionally, a single female plant can produce 600,000 seeds, allowing it to rapidly replenish the soil seedbank. Minimizing Palmer amaranth escapes and preventing its seedbank replenishment requires herbicide programs with multiple sites of action.

Puncturevine Control

Puncturevine control with the pre-emergence herbicide programs was similar 22 days after treatment, with effectiveness ranging from 93% to 100%. This suggests that these herbicides provided effective suppression of puncturevine early in the growing season (data not shown). However, 43 days after treatment, puncturevine control with atrazine was only 65% compared with 75% to 99% with the other pre-emergence herbicide programs. The mixtures of atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a provided 84% to 99% control of puncturevine 43 days after treatment. These herbicide programs provided greater puncturevine control than sole application of Outlook, Warrant, atrazine, or Dual Magnum, indicating the benefit of herbicide mixture for better weed control than single herbicide application (Figure 2).

Crabgrass Control

All the pre-emergence herbicide programs suppressed crabgrass compared to the non-treated control throughout the period of observation. Crabgrass control was similar across the pre-emergence herbicide treatments, with effectiveness ranging from 96% to 100% at 22 days after treatment (data not shown). Crabgrass control at 43 days after treatment was not greater than 70%. All the herbicide treatments provided better crabgrass control compared with atrazine 43 days after treatments. Crabgrass control with FulTime NXT, Calibra, mixtures of atrazine + Calibra, Verdict + Outlook, or Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a was greater than control with Outlook and Warrant alone (Figure 3).

Crop Injury

Sorghum injury 15 days after pre-emergence herbicide treatments ranged from 1.3% to 17%. Treatments with atrazine, atrazine + Callisto, Dual, Dual + Callisto at 5 oz/a, Dual + Callisto at 3 oz/a, Verdict + Outlook, and Warrant resulted in greater injury (10% to 17%) compared to Calibra, Outlook, and Dual + Callisto at 3 or 5 oz/a (<10%). However, sorghum recovered with injury levels of 9% or less at 29 and 43 days after treatment (Table 2). By 43 days after treatment, only Dual, Outlook, Verdict + Outlook, and Dual + Callisto at 3 oz/a caused visual crop injury, and the injury was not greater than 7% (Table 2). These results suggest that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions.

Sorghum Yield

All pre-emergence herbicide treatments resulted in similar sorghum yields, ranging from 69 to 92 bu/a. The pre-emergence application of mixtures of Dual II Magnum + Callisto at rates of 5, 4, 3, or 2 oz/a produced higher yields (92 to 94 bu/a) compared to the nontreated control. However, other pre-emergence herbicide treatments resulted in yields similar to those of the nontreated control (Figure 4). The higher yields observed from herbicide treatments including the mixtures of Dual II Magnum + Callisto may be attributed in part to more effective residual weed control at 43 days after treatment, compared to other herbicide programs.

This study demonstrates that herbicide programs incorporating active ingredients targeting multiple sites-of-action resulted in improved weed control compared to those targeting a single site-of-action. In Kansas, Palmer amaranth has developed metabolic resistance to six herbicide sites-of-action. Additionally, female plants are prolific seed producers and can replenish the soil seedbank. To combat the increasing prevalence of multiple herbicide-resistant weeds, particularly Palmer amaranth, a strategy that prevents seed production is recommended. Therefore, herbicide programs that incorporate active ingredients with multiple sites-of-action, which proved effective in this study, are essential to reduce Palmer amaranth escapes and prevent the replenishment of the soil seedbank.

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Heap, I. (2025). The International Herbicide-Resistant Weed Database. Accessed Wednesday, February 26, 2025. Available online at *www.weedscience.org*

Thompson, C. R., Dille, J. A., & Peterson, D. E. (2019). Weed competition and management in sorghum. Sorghum: A state of the art and future perspectives, 58, 347-360.

Table 1. Preemergence herbicide programs evaluated, active ingredients modes of action and rates of application

Product	Active ingredient*	SOA group #+	Rates
Atrazine	Atrazine	5	1 qt/a
Atrazine + Calibra	Atrazine + (*S*-metolachlor + Mesotrione)	5 + (15+ 27)	1 qt/A + 2.25 qt/a
Calibra	(*S*-metolachlor + Mesotrione)	(15 + 27)	2.25 qt/a
Dual	*S*-metolachlor	15	1.6 pt/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 2 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 3 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 4 oz/a
Dual + Callisto	*S*-metolachlor + Mesotrione	15 + 27	1.6 pt/A + 5 oz/a
FulTime NXT	(Acetochlor + Atrazine)	(15 + 27)	2.25 qt/a
Outlook	Dimethenamid-p	15	18 oz/a
Verdict + Outlook	(Dimethenamid-p + Saflufenacil) + Dimethenamid-p	(14 +15) + 15	10 oz/A +10 oz/a
Warrant	Acetochlor	15	2 qt/a

* Active ingredients in parentheses are premixes.
+ SOA: site-of-action.

Table 2. Sorghum injury at 15, 29, and 43 days after preemergence herbicide treatment (DAT). Means followed by the same letter(s) within a week of observation are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$)

	Injury rating (%)		
Herbicide program	**15 DAT**	**29 DAT**	**43 DAT**
Atrazine	10 ab	2 a	0 a
Atrazine + Calibra	12.5 ab	4.5 a	0 a
Calibra	8.8 ab	0 a	0 a
Dual	15 a	8.8 a	7 a
Dual 1.6 pt/a + Callisto 2oz/a	1.3 b	0 a	0 a
Dual 1.6 pt/a + Callisto 3oz/a	10.5 ab	5 a	1.8 a
Dual 1.6 pt/a + Callisto 4oz/a	2.5 b	0 a	0 a
Dual 1.6 pt/a + Callisto 5oz/a	17 a	0 a	0 a
FulTime NXT	15 a	7 a	0 a
Outlook	7 b	2 a	2 a
Verdict + Outlook	11.3 a	5.8 a	2.5 a
Warrant	11.3 a	4.5 a	0 a

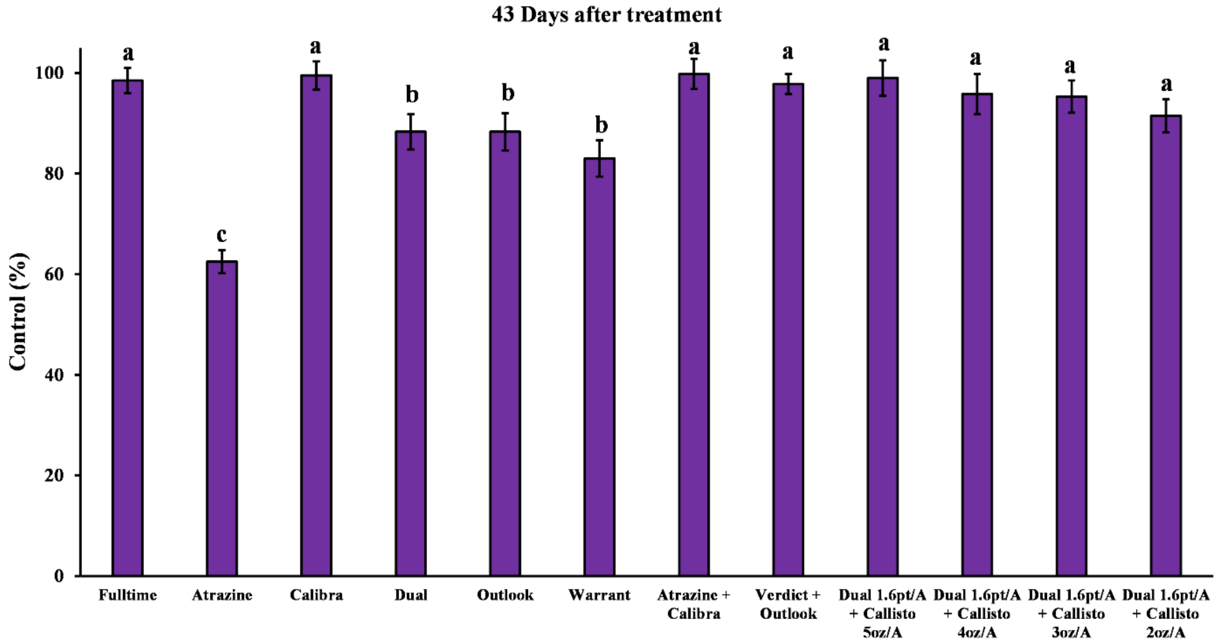

Figure 1. Palmer amaranth control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

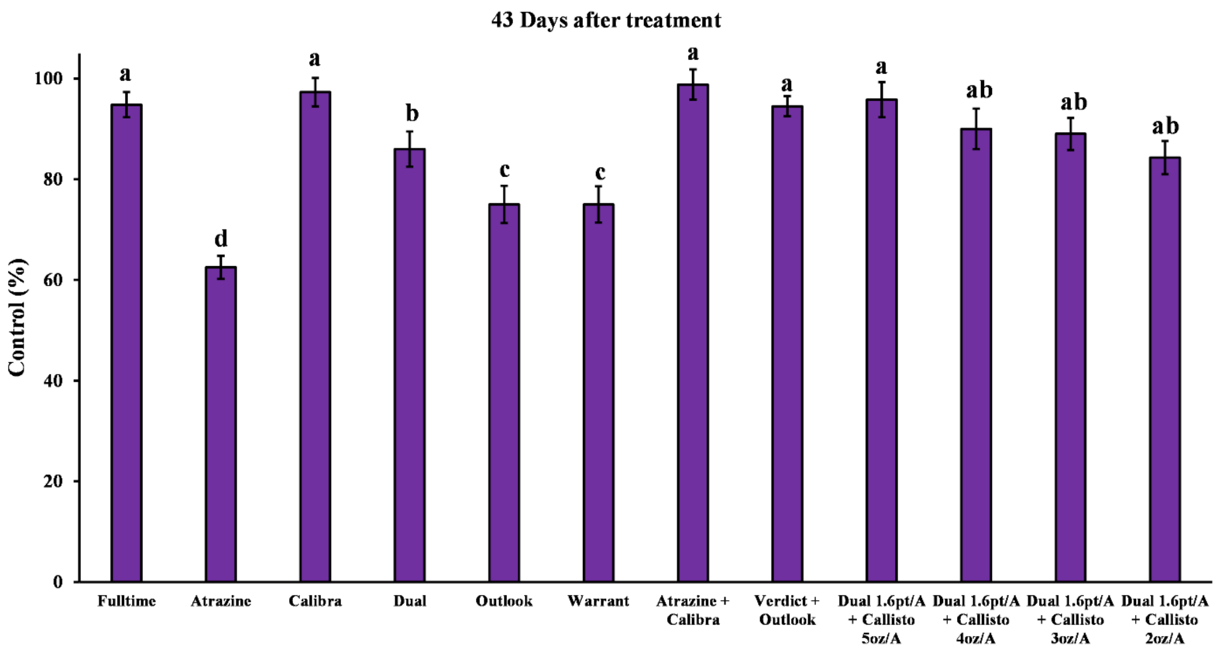

Figure 2. Puncturevine control at 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

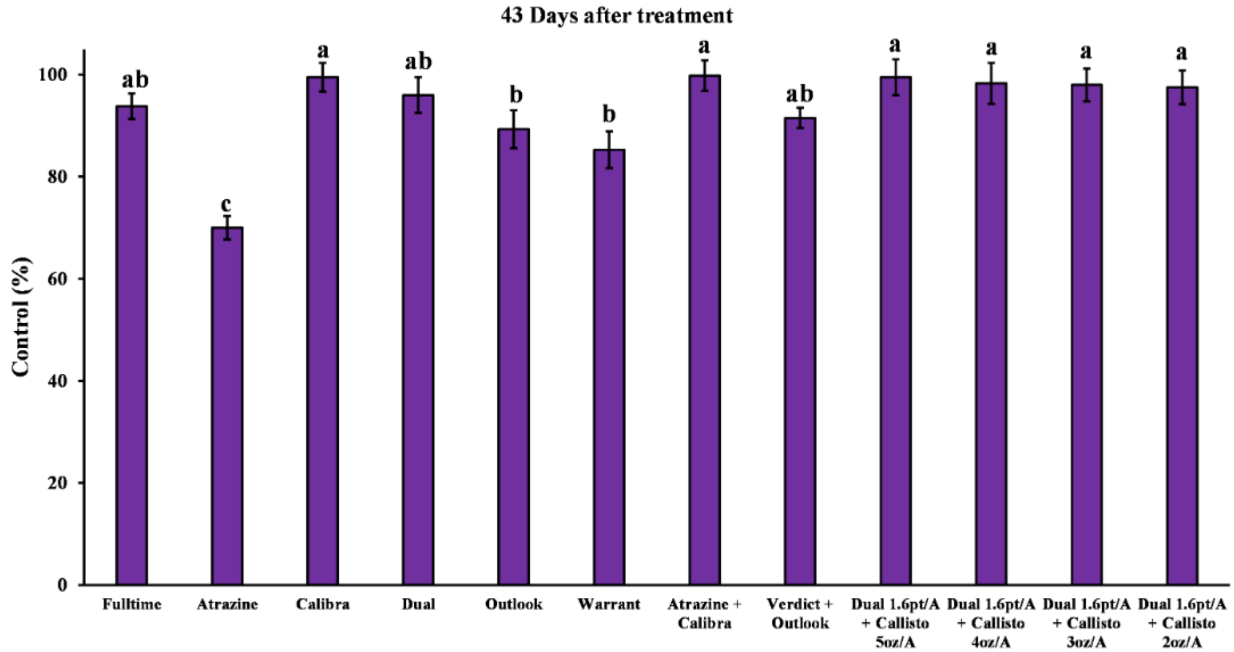

Figure 3. Crabgrass control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).

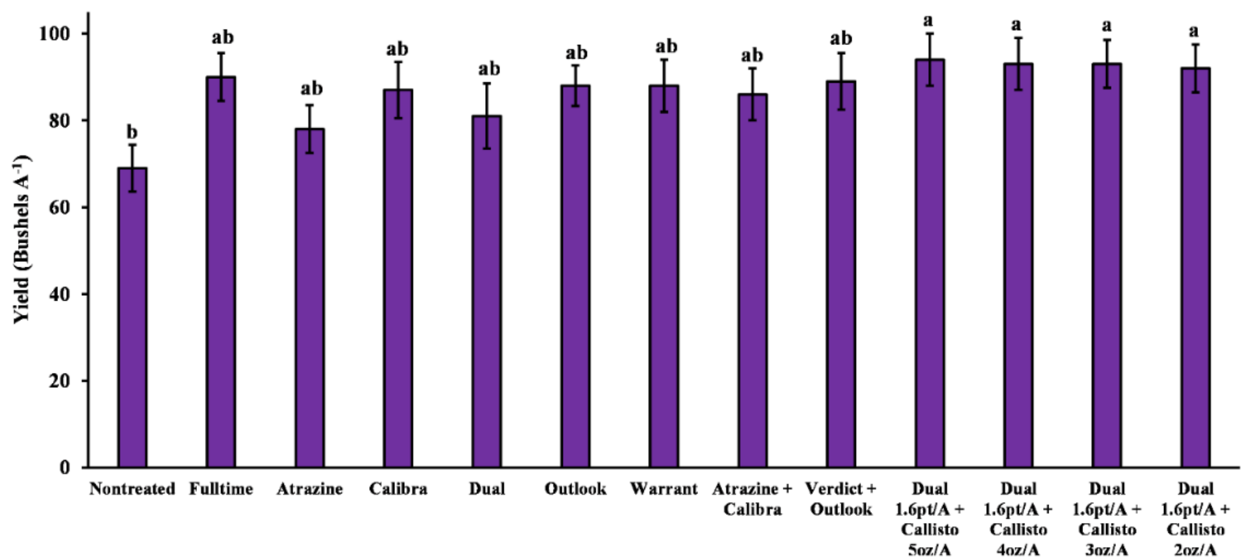

Figure 4. Sorghum yield as affected by pre-emergence herbicide programs. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).