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Overlapping and Mixing Residual Herbicide Programs for 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 to evaluate the effectiveness of overlapping and mixing residual herbicide programs with different sites-of-action for weed control in grain sorghum. Results showed that preemergence herbicide treatments controlled the Palmer amaranth (97%-100%) and puncturevine (97%-99%), 15 days after application. At 43 days after treatment, Outlook + Aatrex 4L and Parallel + Aatrex 4L provided the least control of Palmer amaranth (88%) and puncturevine (61%-74%) compared to other herbicide combinations, including Bicep Lite II Magnum + Callisto, FulTime NXT + Callisto, Lumax EZ + Aatrex 4L, Lumax EZ *fb* Degree Xtra, Lexar EZ, Lumax EZ *fb* Outlook + Aatrex 4L, Outlook + Aatrex 4L and Parallel + Aatrex 4L (97%-100%). Palmer amaranth and puncturevine control with Bicep Lite II Magnum at 1.5 qt/aa + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences, indicating that higher rates of Bicep Lite II Magnum in combination with Callisto did not offer additional weed control benefits compared to the lower rate. Sorghum injury ranged from 2% to 10% 15 days after treatments and was not greater than 4% 22 days after treatment, suggesting that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions. Sorghum yield was not different among the pre-emergence herbicide treatments, ranging from 87 to 98 bu/a. However, the herbicide programs that provided 88% control of Palmer amaranth are not advisable given the prolific seed-producing nature of this weed and its consequences on soil seedbank replenishment and its ability to evolve resistance to herbicides targeting multiple sites-of-action.

Weed management is critical to achieve high yields and a successful harvest in sorghum. However, effective weed control in sorghum production can be challenging. Sorghum is a small-seeded grass and is relatively slow growing in the first few weeks after emergence (Thomson et al., 2019). In addition, sorghum is sensitive to many herbicides that work well on other major crops like corn and soybeans. The combination of slow seedling growth, limited herbicide options, and low application rates creates a challenge for weed control. While grass weeds in established sorghum can be a significant issue, technologies like igrowth sorghum provide solutions for grass control. However, the list of herbicides available for controlling broadleaf weeds after sorghum emerges is limited, and their effectiveness has been reduced due to the development of resistant weeds. One of the most problematic weeds in grain sorghum production in Kansas is Palmer amaranth. This weed has evolved metabolic resistance to 6 herbicide sites-of-action in the state (Heap 2025), is a prolific seed producer with the ability to quickly replenish the soil seedbank. Implementing a strong residual herbicide program is a best management practice for multiple herbicide-resistant weeds such as Palmer amaranth. Previous data on the emergence patterns of glyphosate-resistant Palmer amaranth, using a resistance-simulation model, highlighted the crucial role of residual herbicides in maintaining effective weed control throughout the season and in preventing glyphosate resistant Palmer amaranth seed production (Jha and Norsworthy 2009; Neve et al. 2011). Additionally, maintaining crop fields weed-free, particularly in conservation-tillage systems where preplant tillage is not an option, requires residual herbicides. For slow-growing crops like grain sorghum, an additional application of residual herbicides, before the dissipation of the effectiveness of the initial application, helps reduce selection pressure from relying solely on POST herbicides (Neve et al., 2003). Therefore, the objective of this study was to evaluate the effectiveness of overlapping and mixing residual herbicide programs with different sites-of-action for weed control in no-till dryland grain sorghum production systems of western Kansas.

Procedures

This study was conducted in 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 and puncturevine. The experiment was implemented in a no-till system. The study was arranged in a randomized complete block design with four replications. Plot size was 10 ft by 27 ft. In total, nine pre-emergence herbicide programs were evaluated, including two treatments with overlapping residuals (Table 1). A nontreated control was also included for treatment evaluation. 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 and 22 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). Kansas State University 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%.

Results and Discussion

Palmer Amaranth Control

All pre-emergence herbicide programs effectively suppressed Palmer amaranth compared to the non-treated control throughout the observation period. Palmer amaranth control was comparable across the pre-emergence herbicide treatments, with efficacy ranging from 97% to 100% at 15 days after treatment (data not shown). However, 43 days after treatment, Palmer amaranth control with Outlook + Aatrex 4L and Parallel + Aatrex 4L (88%) was lower relative to other pre-emergence herbicide treatments (98% to 100%). Palmer amaranth control with Bicep Lite II Magnum at

1.5 qt/a + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences (Figure 1), indicating that higher rates of Bicep Lite II Magnum in combination with Callisto did not offer additional weed control benefits compared to the lower rate used in this study. Consequently, using higher rates may increase the cost of weed control without providing added effectiveness.

Puncturevine

All pre-emergence herbicide programs effectively suppressed puncturevine compared to the non-treated control throughout the observation period. Puncturevine control was consistent across the pre-emergence herbicide treatments, with efficacy ranging from 97% to 99% 15 days after treatment (data not shown). However, at 43 days after treatment, control with Outlook + Aatrex 4L (61%) and Parallel + Aatrex 4L (74%) was lower compared to other pre-emergence herbicide treatments (97% to 100%). Puncturevine control with Bicep Lite II Magnum at 1.5 qt/a + Callisto at 5 oz/a or Bicep Lite II Magnum at 1.9 qt/a + Callisto at 5 oz/a showed no differences (Figure 2).

Crop Injury

Sorghum injury 15 days after pre-emergence herbicide treatments ranged from 2% to 10% and was similar among the pre-emergence treatments. Crop injury was not greater than 4% at 22 days after treatment (Table 2), suggesting that these herbicides can be safely applied to sorghum for weed control under favorable environmental conditions.

Sorghum Yield

Sorghum yield was not different among the pre-emergence herbicide treatments, ranging from 87 to 98 bu/a. All the preemergence herbicide treatments resulted in greater yield than the non-treated control (Figure 3). However, treatments with improved control are essential to minimize weed escapes and prevent the replenishment of the weed seedbank as a component of herbicide-resistant management.

This study demonstrates that herbicide programs with overlapping residuals and herbicide mixture with three sites-of-action improved the Palmer amaranth control. Palmer amaranth has evolved metabolic resistance to six different herbicide sites-of-action in Kansas. Given the prolific seed production of female plants and their ability to replenish the soil seedbank, a zero seed-production strategy is recommended to manage the increase of multiple herbicide-resistant weeds, particularly Palmer amaranth. Therefore, herbicide programs that incorporate active ingredients with multiple sites-of-action and overlapping residual effects are essential. These strategies showed improved control in this study and are crucial for minimizing Palmer amaranth escapes and preventing the replenishment of the soil seedbank. This study needs to be replicated in time and space to fully represent the variability across different soil types and environmental conditions.

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Table1. Preemergence herbicide programs evaluated, active ingredients, modes of action and rates of application

Product*	Active ingredient$	SOA group #+	Rates
Aatrex 4L + Outlook	Atrazine + Dimethenamid-p	5 + 15	0.5 oz/a +14 oz/a
Aatrex 4L + Parallel	Atrazine + Metolachlor	5 + 15	1 qt/a + 1.3 qt/a
Aatrex 4L + Lumax EZ	Atrazine + (*S*-metolachlor + Atrazine + Mesotrione)	5 + (5 + 15 + 27)	0.6 qt/a + 2.7 qt/a
Bicep Lite II Magnum + Callisto	(Atrazine + *S*-metolachlor) + Mesotrione	(5 + 15) + 27	1.5 qt/a + 5 oz/a
Bicep Lite II Magnum + Callisto	(Atrazine + *S*-metolachlor) + Mesotrione	5 + 15 + 27	1.9 qt/a + 5 oz/a
FulTime NXT + Callisto	(Atrazine + Acetochlor) + Mesotrione	(5 + 15) + 27	3 qt/a + 4 oz/a
Lumax EZ *fb* Degree Xtra	(Atrazine + *S*-metolachlor + Mesotrione) *fb* (Atrazine + Acetochlor)	(5 + 15 + 27) *fb* (5 + 15)	2.7 qt/a *fb* 2.5 qt/a
Lexar EZ	(Atrazine + *S*-metolachlor + Mesotrione)	(5 + 15 + 27)	3 qt/a
Lumax EZ *fb* Outlook + Aatrex 4L	(Atrazine + *S*-metolachlor + Mesotrione) *fb* Dimethenamid-p + Atrazine	(5 + 15 + 27) *fb* 5 + 15	2.7 qt/a *fb* 14 oz/a + 0.5 oz/a

[*] *fb:* followed by
[$] active ingredients in parentheses are premixes.
[+] SOA: site-of-action

Table 2. Sorghum injury 15 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 ($P > 0.1$)

Treatments*	15 DAT	22 DAT
Aatrex 4L + Outlook	3 a	0 a
Aatrex 4L + Parallel	5 a	0 a
Aatrex 4L + Lumax EZ	2 a	1.3 a
Bicep Lite II Magnum + Callisto	5 a	1.3 a
Bicep Lite II Magnum + Callisto	5 a	0.5 a
FulTime NXT + Callisto	5 a	1.3 a
Lumax EZ *fb* Degree Xtra	10 a	4 a
Lexar EZ	5 a	2.5 a
Lumax EZ *fb* Outlook + Aatrex 4L	5 a	5 a

[*] Abbreviations: *fb*: followed by

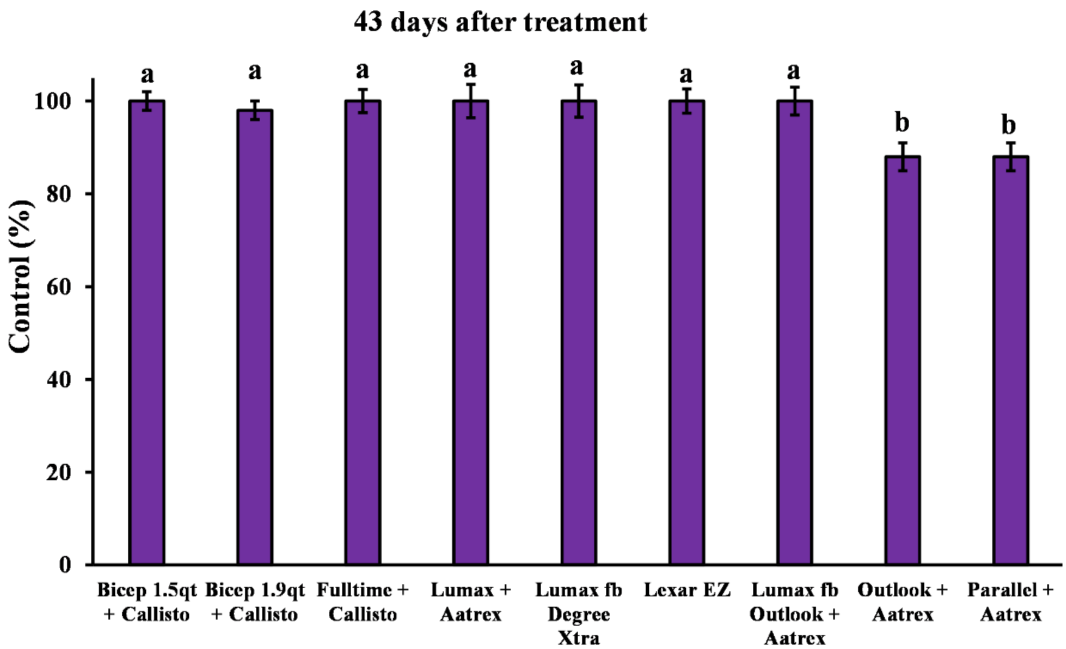

Figure 1. Palmer amaranth control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$).

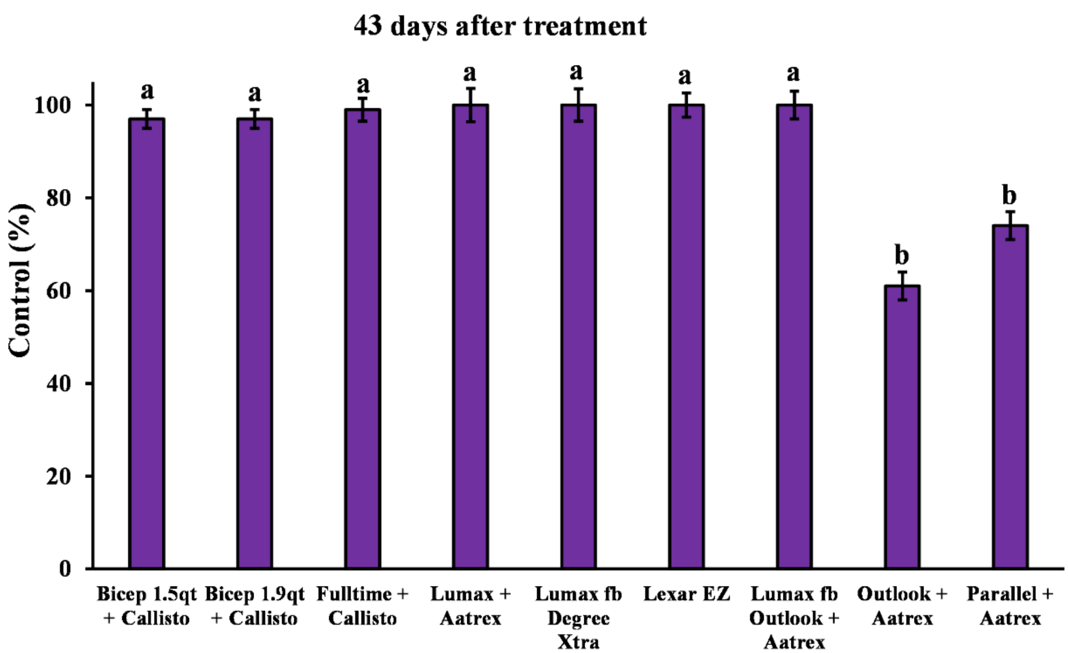

Figure 2. Puncturevine control 43 days after preemergence herbicide treatment. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.1$).

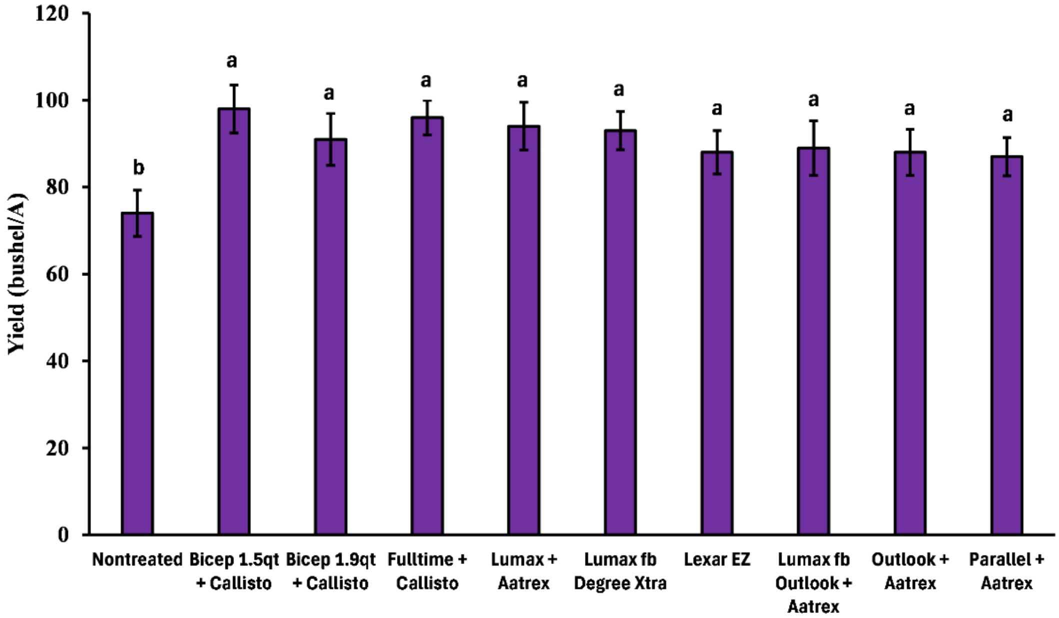

Figure 3. Sorghum yield as affected by pre-emergence herbicide programs. Error bars represent one standard error of the mean. Means followed by the same letter(s) are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure (*P* > 0.1).