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Allelopathic Potential of Winter Wheat Varieties for Weed Suppression

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Allelopathic Potential of Winter Wheat Varieties for Weed Suppression

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Summary

Summer weeds are an expensive economic and environmental problem during the fallow period following the harvest of a wheat crop. Anecdotal evidence suggests that different wheat varieties impact the need for weed control in the subsequent fallow period differently, with reasons ranging from residue amount and quality to the allelopathic potential of such residue. Thus, our objectives were to compare the allelopathic effects of different winter wheat varieties on weed and crop germination suppression. We collected the residue left after harvest of 25 varieties grown in a randomized complete block design in two Kansas locations (Hays and Great Bend) during 2022. The residue of the different varieties were combined (replications within location), dried, ground, and used to create extracts with 5% concentration that were later used in a growth chamber study. A total of 50 seeds for weed species Palmer amaranth (*Amaranthus palmeri*) and giant foxtail (*Setaria faberi*), and 25 seeds for grain sorghum (*Sorghum bicolor*), were added to petri dishes in combination with 5 mL of each extract in four replicates. Petri dishes were sealed with Parafilm and placed in a dark growth chamber set to 84/75°F day/night temperatures. Seed germination was counted after 5 days. There were significant location by variety interactions in the control of both weed species, with greater weed control resulting from the residue derived from Great Bend (6–100% control) than from Hays (-10 to 69%). The difference among varieties was also large, and depending on weed species and location, ranged from as little as 26% to as much as 90% (these differences reflected contrasts between the varieties with minimum versus those with maximum control). All wheat varieties significantly reduced seed germination of Palmer amaranth and giant foxtail, but varieties differed in their germination suppression potential. The allelopathic effects of wheat varieties could be additional targets of breeding programs for reduced weed pressure. Meanwhile, grain sorghum germination was minimally impacted by allelopathic effects of wheat residue.

Introduction

Winter wheat is the predominant crop in the U.S. Central Great Plains due to its broad adaptability (Lollato et al., 2020a) and good match between crop demand for water and precipitation distribution (Couëdel et al., 2021; Lollato et al., 2017, 2020b; Sciarresi et al., 2019). About half of the wheat acreage is grown after a short summer fallow in the central portion of Kansas, and about 75% of the acreage is grown after a long (11 to 14 months) fallow in western Kansas (Jaenisch et al., 2021). Summer weeds on fallow ground following wheat harvest are a costly problem for Kansas growers. These include

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both economical costs associated with weed control, and environmental costs associated with weeds' consumption of water and nutrients.

After harvest, the wheat crop leaves a large amount of residue in the ground that can impact moisture retention and yield of the subsequent crop (Simão et al., 2021, 2023) as well as management of summer weeds (Simão et al., 2020). Similarly to grain yield (e.g., Munaro et al., 2020), wheat varieties differ in the amount and quality of residue left behind. Growers report that weed pressure can vary in different fields depending on which wheat variety was grown in the preceding season, but evidence is anecdotal. A potential explanation for different weed pressures include the amount and quality of biomass residue left after harvest. Another potential explanation, which was the focus of this study, is whether wheat varieties' residues differ in allelopathic effects, potentially suppressing weed germination. Thus, the objective of this study was to compare the allelopathic effects of different winter wheat varieties on weed and crop germination suppression.

Procedures

We collected winter wheat residue left on the field immediately after harvest from a study evaluating 25 winter wheat varieties. The study was conducted in a randomized complete block design with four replicates in Great Bend and Hays, KS. Sharper, a broadleaf herbicide, was applied at 2 fl oz/a four days prior to harvest at Great Bend as a pre-harvest weed control strategy.

Within location, wheat residue was collected from all replicates for a given variety and combined into a homogenous sample. Samples were dried at 140°F for 48 h and ground to form a fine powder, which was steeped in deionized (DI) water for 44 hours to generate extracts with 5% concentration.

To evaluate the potential allelopathic effect of the extract of different wheat varieties' residue on crop and weed germination, seeds of two weed species and one summer crop species were placed on top of filter paper in Petri dishes. A total of 50 seeds were used for weed species Palmer amaranth (*Amaranthus palmeri*) and giant foxtail (*Setaria faberi*), and 25 seeds were used for grain sorghum (*Sorghum bicolor*). Then, we added 5 ml of each extract into petri dishes in four replicates of each of the three seed species.

For each species, the growth chamber study was established as a two-way factorial (location × variety) plus control. The control consisted of de-ionized water for baseline germination estimate. Petri dishes were sealed with Parafilm and placed in a dark growth chamber set to 84/75°F day/night temperatures. Seed germination was counted after 5 days (Figure 1). Seed germination for each treatment was calculated as percentage of control. This dataset was then subjected to two-way analysis of variance (ANOVA) using variety, location, and their interaction as fixed factors, and replication nested within location as random factor.

Results

Wheat varieties differed in allelopathic effects on weed germination, holding a potential for use as biological weed control (Tables 1 and 2).

The ANOVA evaluation of percent reduction in giant foxtail seed germination suggested that the interaction between location and variety was significant (P = 0.0007, Figure 2). There was a greater percent reduction in foxtail germination in Great Bend (72–100%) than in Hays (-10 to 69%). Wheat varieties differed in their suppression of germination, with a larger variety-induced range in germination reduction in Hays (range of ~79% from minimum to maximum control) than in Great Bend (range: 28%).

The ANOVA for Palmer amaranth seed germination relative to the control also suggested a significant interaction between location and variety ($P < 0.0001$, Figure 3). There was a greater Palmer amaranth germination reduction in Great Bend (6–96%) as compared to Hays (20–46%). Varieties differed in their germination suppression potential, with a greater range in germination reduction potential in Great Bend (range of 90% between minimum and maximum control) than in Hays (range: 26%).

Given that the overall weed suppression control was greater in Great Bend than in Hays, we believe that the pre-harvest application of Sharpen herbicide may have contributed to the greater reduction in weed seed germination measured in this location.

Regarding reduction in grain sorghum germination, the variety × location interaction was not significant, but varieties impacted grain sorghum germination ($P = 0.047$; Figure 4). We note that while grain sorghum germination was significantly reduced by the presence of wheat extract as compared to the control, this germination suppression only ranged from 2–14%, which was considerably lower than for weeds (range: 6–100%).

Preliminary Conclusions

All wheat varieties significantly reduced seed germination of Palmer amaranth and giant foxtail, but varieties differed in their germination suppression potential. The allelopathic effects of wheat varieties could be additional targets of breeding programs for reduced weed pressure. Future studies could also focus on other weed-controlling traits such as canopy architecture and light interception, residue amount, and carbon-to-nitrogen ratio.

Locations played an important role on wheat's allelopathic effects, perhaps due to pre-harvest application of Sharper herbicide. Grain sorghum germination was minimally impacted by allelopathic effects of wheat residue.

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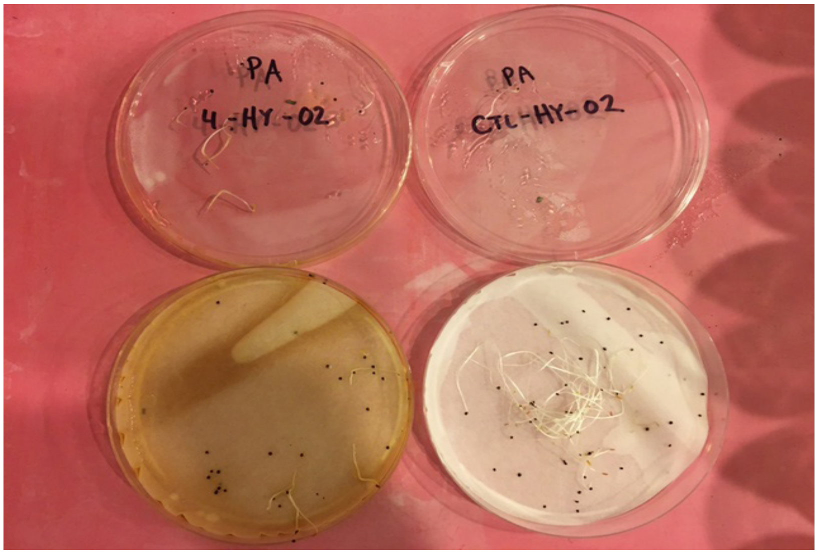

Figure 1. Palmer amaranth seed germination after 5 days for the wheat variety Duster (left) versus the de-ionized water control (right).

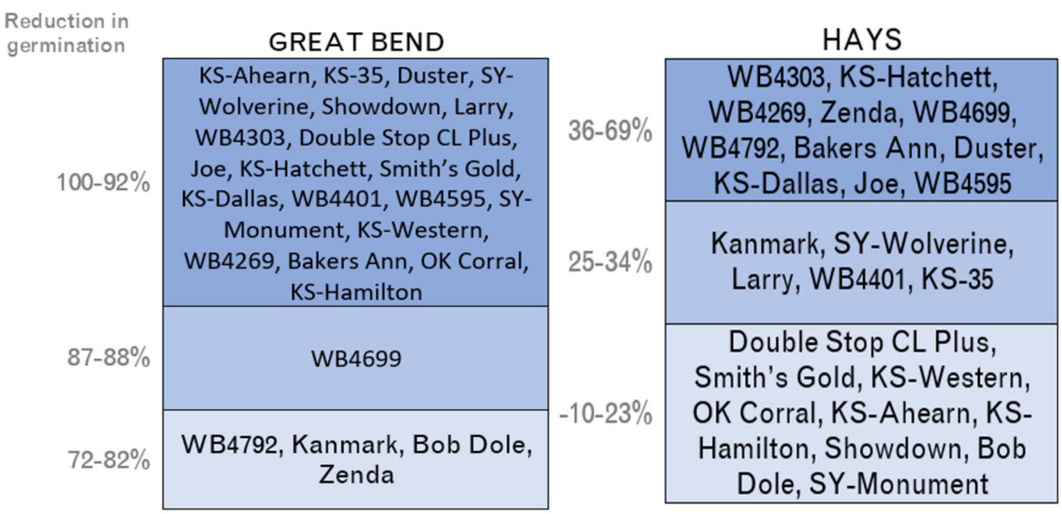

Figure 2. Percent reduction in giant foxtail seed germination relative to the control as impacted by the significant interaction between 25 winter wheat varieties and two locations (Great Bend, left; and Hays, right) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at *P* < 0.05.

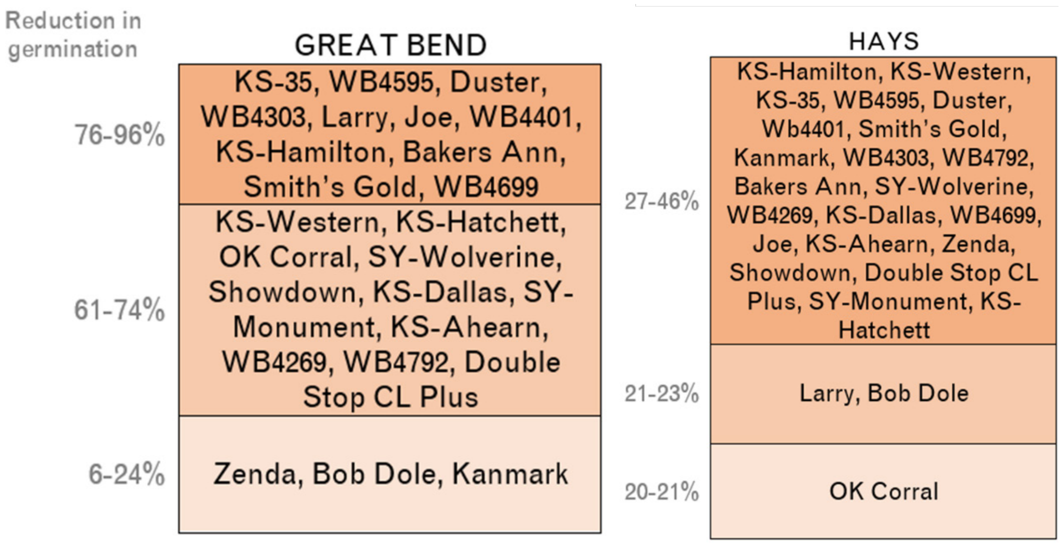

Figure 3. Percent reduction in Palmer amaranth seed germination relative to the control as impacted by the significant interaction between 25 winter wheat varieties and two locations (Great Bend, left; and Hays, right) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at $P < 0.05$.

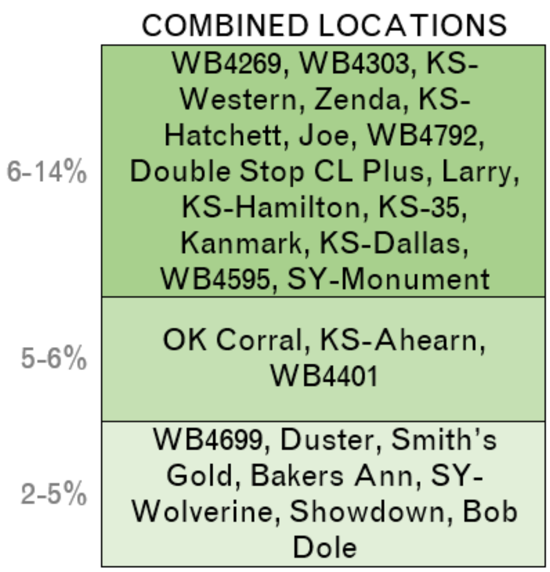

Figure 4. Percent reduction in grain sorghum seed germination relative to the control as impacted by the main effect of 25 winter wheat varieties combined across two locations (Great Bend and Hays) following the 2022 winter wheat growing season. Wheat varieties placed within the highest or the lowest groups did not differ statistically from each other according to the Tukey's test at $P < 0.05$.