ALLELOPATHIC POTENTIAL OF WHEAT, RYE, AND RADISH ON CROP AND WEED SEED GERMINATION

by

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Abstract

Herbicide-resistant weeds have become a growing concern, increasing the need for alternative weed control methods. Natural chemical defense mechanisms in plants can inhibit the germination and growth of other surrounding plants to reduce competition, known as allelopathy. The objective of this study was to consider the allelopathic potential of hard red winter wheat, rye, and tillage radish varieties on grain sorghum, giant foxtail, and Palmer amaranth seeds. Crop treatments were eight wheat, three rye, and one radish planted and grown for eight weeks in a greenhouse. After harvesting and drying the plant biomass, 2.5% extracts were produced by soaking 2.5 g plant biomass in 100 ml water. Extracts were placed in Petri dishes with the seeds as well as a water-only control. Petri dishes were sealed, placed in a growth chamber and seed germination recorded every 48 hours. Three runs were completed with four replications of each treatment in each run. Sorghum germination was largely unaffected by the crop treatments, while the weed seeds responded to the crop treatments. Aroostook rye, Grainfield wheat, and Zenda wheat treatments resulted in significantly less germination of giant foxtail than the control in all three runs, while Everest and Duster wheats reduced germination in two of three runs. Grainfield wheat also resulted in significantly less germination of Palmer amaranth than the control in all three runs, while Zenda wheat and Aroostook rye did so in two out of three runs. These results suggest that dry plant residues of Grainfield and Zenda wheat varieties and Aroostook rye could inhibit the germination of both Palmer amaranth and giant foxtail seeds. The next step would be to evaluate their potential to reduce weed seed germination and seedling emergence when these crops are planted in the field as an alternative weed control method.

Introduction

Herbicides play an important role in agriculture and allow for the use of other farming practices, such as no-till. Over the last several years, weeds have been developing resistance to herbicides commonly used in production agriculture. Herbicide resistant weeds are a growing concern in agriculture due to the shrinking number of viable chemical options available. Producers are in need of alternative weed control methods to deal with resistant weeds. One of these methods that is beginning to be incorporated into weed management is the use of cover crops.

Allelopathy is defined as a natural chemical defense mechanism in plants that can affect the germination and growth of other surrounding plants to reduce competition (Teasdale et al., 2012). These plants produce allelochemicals in the roots, stems, and leaves that are released into the soil either through secretion from the root structures or decomposition of above ground residues. Annual plants with allelopathic properties have the potential to be incorporated into cropping systems for the purpose of weed control as cover crops. Winter rye (*Secale cereale*) is one cover crop that fits this description.

Rye is a winter annual plant known to have allelopathic properties that inhibit germination of seeds in the soil (Weston and Duke, 2003). It is commonly used as a cover crop in corn (*Zea mays*) and soybean (*Glycine max*) rotations. There is concern among producers for its use in wheat production due to the fact that it is considered a weed in those systems. Publications have indicated that there may be hard red winter wheat (*Triticum aestivum*) varieties that have these same characteristics of allelopathy (High Plains Journal, 2017; Ehmke, 2016). Wheat with these traits could provide farmers with another cover crop option in terms of weed control.

Winter wheat is commonly followed by a fallow period or immediately with another crop (double-crop) in most wheat rotations. Weed control in fallow is important to conserve soil water and prevent additions to the weed seed bank in the soil. Weed control in a double-crop system is important to prevent yield losses from competition for resources. Allelopathic wheat varieties could have the potential to extend weed control after harvest to reduce the need for herbicides in these fallow and double-crop periods; however, there is concern that the allelochemicals could have an effect on germination of the succeeding crop planted in the double-crop system. Discovering the potential of wheat varieties to inhibit germination weed seeds could provide another useful trait to select for in wheat breeding programs. The objective of this study was to consider the allelopathic potential of hard red winter wheat, rye, and tillage radish (*Raphanus raphanistrum*) varieties on grain sorghum (*Sorghum bicolor*), giant foxtail (*Setaria faberi*), and Palmer amaranth (*Amaranthus palmeri*) seeds.

Methods

Eight varieties of wheat were selected and tested alongside three varieties of rye and one variety of tillage radish (Table 1). Extracts formed from dry plant biomass were tested on grain sorghum, giant foxtail, and Palmer amaranth seeds, with germination being the response variable that was measured. The twelve subjects of wheat, rye, and tillage radish were tested on the three different crop and weed seeds, totaling 48 treatments. Four replications were done of each treatment.

Subjects were planted and grown for approximately eight weeks in February-April of 2019, until there was enough plant biomass for testing. Plant biomass was harvested and dried in paper bags in the greenhouse. The extract solutions were produced similar to Machado (2006) methods. Plant material was shredded and soaked in deionized water to produce 2.5% extracts. The first and third runs were completed with extracts created by soaking 2.5 grams of plant biomass in 100 milliliters of water, while the second test had extracts made from soaking 5 grams of plant biomass in 200 milliliters of water. To contain the plant biomass, the shredded material was placed in tea ball infusers to soak in the first run, while material was placed in tied flour bag towel pieces in the second and third runs. Each sample of biomass soaked for 42 hours in all three experiment replications. Runs were completed in April 2019, November 2019, and September 2020.

One filter paper was placed in the bottom of each Petri dish with 25 seeds of the target crop, or 50 seeds of the target weed placed on top of the filter paper. Extract was pipetted onto the seeds and bottom filter paper at a volume of five ml. Another five ml of water were added to the crop seeds. A single filter paper was placed on top of the seeds and extract. Then, the petri dishes were closed and sealed with parafilm. A water-only control was included with similar methods for comparison. The dishes were placed in a dark growth chamber at twelve hours of 25ºC and twelve hours of 15ºC. Data were recorded after two, four, and six days, which was approximately when seeds stopped germinating. A count of the number of seeds that had germinated in each Petri dish was taken on each data recording day, and the seeds that had germinated were removed from the dish.

Each run had a total of four replications of each treatment and three runs were completed in total. Percent germination of the control was calculated by dividing the mean of each treatment in each run by the mean of the control in its respective run. Data were subjected to ANOVA analysis in SigmaPlot (v12.5). Means were separated at the alpha = 0.05 level.

Results and Discussion

The percent germination for each treatment relative to the control on giant foxtail, Palmer amaranth, and sorghum seeds are shown in Table 1. The effects of treatments on weed seeds are also displayed in Figure 1 split up for each run . The letters above each bar depict significance at the alpha = 0.05 level.

Sorghum seed germination was relatively unaffected by the treatments (Table 1). Germination in the presence of Grainfield wheat and Aroostook rye were significantly different from the other species in run two, but significance was not observed in any other runs with sorghum. Weed seed germination did respond to the treatments in all three runs(Figure 2). Data for Redhawk wheat was removed from the third run of tests due to mold growth in the petri dishes affecting seed germination.

In the first run of tests on giant foxtail seed, Zenda wheat, Grainfield wheat, Aroostook rye, and Everest wheat treatments all reduced germination as compared to the control (Table 1). Zenda wheat also resulted in significantly lower germination than among all potential cover crop species except for Grainfield wheat. The second run of tests resulted in lower germination than the control for Grainfield wheat, Zenda wheat, Aroostook rye, and Duster wheat. Grainfield wheat treatment was significantly lower than all other treatments except for Zenda wheat and Aroostook rye, and all three of these were lower than the bottom four treatments. All treatments except for the radish and Winter King rye reduced germination compared to the control in the third run , and Aroostook rye had significantly lower giant foxtail germination than half of the treatments evaluated.

Palmer amaranth germination was reduced relative to the control by half of the treatments in the first run , with Mint and Zenda wheat treatments producing similar results of less germination than the rest of the subjects. Run two resulted in all treatments having reduced germination, with Aroostook rye causing the lowest germination among all treatments except Grainfield wheat and Grainfield wheat had less germination compared to all but Zenda wheat and Aroostook rye. Five treatments reduced germination in the third run, with Elbon and Aroostook rye varieties having lower germination than Larry and Zenda wheats.

Table 1: Percent Germination of Giant Foxtail, Palmer Amaranth, and Sorghum seeds relative to the germination of the control for each treatment and each run.

	Giant Foxtail			Palmer Amaranth			Sorghum		
Treatment	**Run**								
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Aroostook Rye	85%	51%	38%	96%	25%	61%	95%	85%	95%
Byrd Wheat	89%	72%	72%	70%	72%	78%	102%	89%	93%
Duster Wheat	96%	66%	57%	78%	68%	80%	100%	96%	91%
Elbon Rye	89%	90%	67%	81%	72%	58%	99%	97%	91%
Everest Wheat	85%	82%	60%	82%	69%	78%	97%	97%	99%
Grainfield Wheat	77%	31%	48%	74%	35%	73%	102%	101%	89%
Larry Wheat	98%	76%	62%	95%	76%	87%	93%	90%	96%
Mint Wheat	86%	74%	68%	38%	59%	79%	98%	92%	93%
Radish	93%	90%	79%	85%	58%	62%	98%	96%	94%
Redhawk Wheat	89%	94%	0%	74%	63%	14%	99%	94%	97%
Winter King Rye	93%	75%	80%	87%	65%	66%	98%	93%	91%
Zenda Wheat	68%	50%	57%	46%	57%	90%	98%	89%	89%
Control	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure 1: Percent germination relative to the control for Giant Foxtail and Palmer Amaranth.

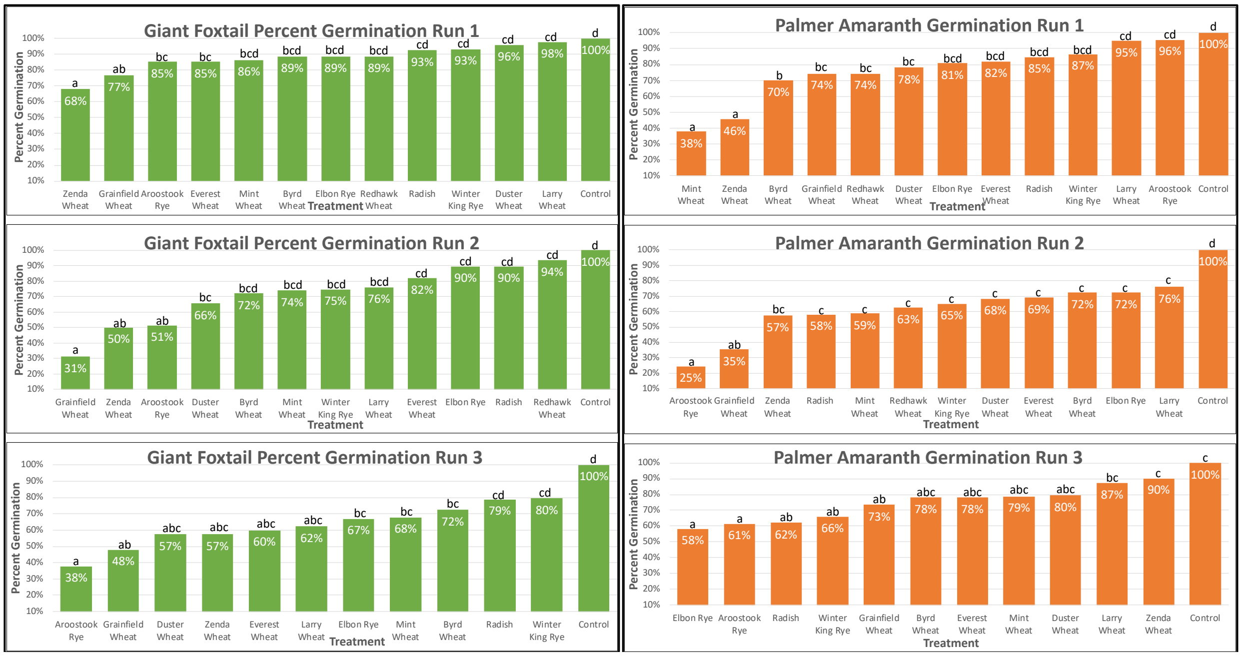

Figure 2: Treatment listing in order of lowest germination to highest germination. Top five in each run are listed with shadings highlighting trends across runs.

Top Five Treatment Listing:
Low to High Giant Foxtail Germination

Run 1	Run 2	Run 3
Zenda Wheat (a)	Grainfield Wheat (a)	Aroostook Rye (a)
Grainfield Wheat (ab)	Zenda Wheat (ab)	Grainfield Wheat (ab)
Aroostook Rye (bc)	Aroostook Rye (ab)	Duster Wheat (abc)
Everest Wheat (bc)	Duster Wheat (bc)	Zenda Wheat (abc)
Mint Wheat (bcd)	Byrd Wheat (bcd)	Everest Wheat (abc)

Top Five Treatment Listing:
Low to High Palmer Amaranth Germination

Run 1	Run 2	Run 3
Mint Wheat (a)	Aroostook Rye (a)	Elbon Rye (a)
Zenda Wheat (a)	Grainfield Wheat (ab)	Aroostook Rye (a)
Byrd Wheat (b)	Zenda Wheat (bc)	Radish (ab)
Grainfield Wheat (bc)	Radish (c)	Winter King Rye (ab)
Redhawk Wheat (bc)	Mint Wheat (c)	Grainfield Wheat (ab)

Treatments listed in Figure 2 were the five treatments in each run that reduced germination the most, accompanied by letters denoting statistical significance at the alpha = 0.05 level. The control was denoted by the letter “d” in all runs except for Palmer amaranth in the third run, which was denoted by the letter “c”. Aroostook rye, Grainfield wheat, and Zenda wheat treatments resulted in significantly less germination of giant foxtail than the control in all three runs. Everest and Duster wheats reduced germination in two of three runs. Grainfield wheat also resulted in significantly less germination of Palmer amaranth than the control in all three runs. Zenda wheat and Aroostook rye reduced germination in two out of three runs.

Conclusion

These results suggest that there are varietal differences in wheat and rye for allelopathic potential. The effects of the treatments were seen on weed seed germination, while the crop seed germination was unaffected. These suggested varietal differences in the allelopathic properties of wheat and rye varieties could be a tool for weed control via cover crops, with the potential to be incorporated into double-crop situations for weed control without causing harm to the succeeding crop. Future steps are to test reduction in weed seed germination and emergence in a field setting as an alternative weed control method.

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