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Response of Dicamba/Fluroxypyr/Glyphosate-Resistant Kochia to Atrazine and Alternative Postemergence Herbicides

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Response of Dicamba/Fluroxypyr/Glyphosate-Resistant Kochia to Atrazine and Alternative Postemergence Herbicides

Abstract

Two kochia accessions (KS-4A and KS-4H) were previously identified from a corn field near Garden City, KS, with multiple resistance to glyphosate (Roundup PowerMax), dicamba (Clarity), and fluroxypyr (Starane Ultra). The objectives of this research were to (1) determine the response of these kochia accessions to preemergence (PRE) and postemergence (POST) applied atrazine (Aatrex) in dose-response assays, and (2) determine the effectiveness of alternative POST herbicides. Seeds of a known susceptible kochia accession (SUS) collected from research fields in Hays, KS, were used for comparison. Greenhouse experiments were conducted at the Kansas State University Agricultural Research Center near Hays, KS, in a randomized complete block design with 4 to 12 replications. For Aatrex PRE dose-response assay, germination trays (each 10- × 10-inch) containing field soil were used. Fifty seeds from each accession were separately sown on the soil surface in each tray. PRE applied Aatrex doses, including 0, 1/4X, 1/2X, 1X, 2X, and 4X (1X of Aatrex = 32 oz/a) were tested. Emerged kochia seedlings from each tray were counted 28 days after treatment (DAT). For Aatrex POST dose-response assay, kochia plants from SUS and KS-4H accessions were grown in 4- × 4-inch pots containing commercial potting mixture. The same doses of Aatrex (as for PRE dose-response) were tested on 3- to 4-inch tall kochia plants. In a separate greenhouse study, the SUS and KS-4H accessions were also tested with alternative POST herbicides. Data on percent visual control and shoot biomass were collected at 21 DAT in both Aatrex POST and alternative POST herbicide studies. Results indicated that the effective dose (ED50 values) of PRE applied Aatrex required for 50% reduction in seedling emergence of KS-4A, KS-4H, and SUS was 129, 7, and 1 oz/a, respectively, indicating 129- and 7- fold resistance in KS-4A and KS-4H accessions. Furthermore, the KS-4H accession showed 248-fold resistance to POST applied Aatrex, as compared to SUS accession. Among alternative POST herbicide programs, Gramoxone, Huskie, Talinor, and Sharpen alone or with 2,4-D provided excellent control (96-100%) of SUS and KS-4H accession at 21 DAT. In conclusion, these results indicate that dicamba/ fluroxypyr/glyphosate-resistant kochia from Garden City, KS, are also highly resistant to PRE and POST applied atrazine. However, alternative POST herbicides such as Huskie, Talinor, Gramoxone, Sharpen alone, or with 2,4-D were effective control options for this multiple resistant kochia accessions.

Keywords

Atrazine resistance, kochia, multiple herbicide resistance

Authors

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Summary

Two kochia accessions (KS-4A and KS-4H) were previously identified from a corn field near Garden City, KS, with multiple resistance to glyphosate (Roundup PowerMax), dicamba (Clarity), and fluroxypyr (Starane Ultra). The objectives of this research were to (1) determine the response of these kochia accessions to preemergence (PRE) and postemergence (POST) applied atrazine (Aatrex) in dose-response assays, and (2) determine the effectiveness of alternative POST herbicides. Seeds of a known susceptible kochia accession (SUS) collected from research fields in Hays, KS, were used for comparison. Greenhouse experiments were conducted at the Kansas State University Agricultural Research Center near Hays, KS, in a randomized complete block design with 4 to 12 replications. For Aatrex PRE dose-response assay, germination trays (each 10- × 10-inch) containing field soil were used. Fifty seeds from each accession were separately sown on the soil surface in each tray. PRE applied Aatrex doses, including 0, 1/4X, 1/2X, 1X, 2X, and 4X (1X of Aatrex = 32 oz/a) were tested. Emerged kochia seedlings from each tray were counted 28 days after treatment (DAT). For Aatrex POST dose-response assay, kochia plants from SUS and KS-4H accessions were grown in 4- × 4-inch pots containing commercial potting mixture. The same doses of Aatrex (as for PRE dose-response) were tested on 3- to 4-inch tall kochia plants. In a separate greenhouse study, the SUS and KS-4H accessions were also tested with alternative POST herbicides. Data on percent visual control and shoot biomass were collected at 21 DAT in both Aatrex POST and alternative POST herbicide studies. Results indicated that the effective dose (ED_{50} values) of PRE applied Aatrex required for 50% reduction in seedling emergence of KS-4A, KS-4H, and SUS was 129, 7, and 1 oz/a, respectively, indicating 129- and 7- fold resistance in KS-4A and KS-4H accessions. Furthermore, the KS-4H accession showed 248-fold resistance to POST applied Aatrex, as compared to SUS accession. Among alternative POST herbicide programs, Gramoxone, Huskie, Talinor, and Sharpen alone or with 2,4-D provided excellent control (96-100%) of SUS and KS-4H accession at 21 DAT. In conclusion, these results indicate that dicamba/fluroxypyr/glyphosate-resistant kochia plants from Garden City, KS, are also highly resistant to PRE and POST applied atrazine. However, alternative POST herbicides such as Huskie, Talinor, Gramoxone, Sharpen alone, or with 2,4-D were effective control options for these multiple resistant kochia accessions.

Introduction

Kochia (*Bassia scoparia* L.) is a highly invasive and troublesome weed species across the United States Great Plains, including Kansas (Kumar et al., 2018a). It has an extended emergence period from early spring through late summer (Dille et al., 2017; Kumar et al., 2018b). Kochia has an aggressive growth habit and it can tolerate various abiotic stresses such as cold, heat, drought, and salinity (Friesen et al., 2009; Kumar et al., 2018a). Kochia has high outcrossing potential and can exchange genes between and among field populations (Beckie et al. 2016). Kochia plants produce a lot of seeds (a single plant can produce >100,000 seeds) and spread those seeds through wind-mediated tumbling of matured plants in late fall (Kumar et al., 2018a). Season-long competition from kochia in soybean, corn, and sorghum can reduce grain yields by 30 to 40% (Kumar et al., 2018a).

Kochia also has a high tendency to evolve herbicide resistance (Heap 2020). In 2017, kochia accessions were identified from corn fields near Garden City, KS, with multiple resistance to glyphosate, dicamba, and fluroxypyr (Kumar et al., 2019). About 3.1- to 9.4-fold resistance to dicamba, 3.0- to 8.6-fold resistance to fluroxypyr, and 3- to 13-fold increase in EPSPS gene copies (target site of glyphosate) were found in these kochia accessions (Kumar et al., 2019). However, the response of these multiple resistant kochia accessions to atrazine (Aatrex) and other alternative POST herbicides is unknown. The main purpose of this study was to (1) determine the response of these kochia accessions to preemergence (PRE) and postemergence (POST) applied atrazine (Aatrex) in dose-response assays, and (2) determine the effectiveness of alternative POST herbicides.

Procedures

Fully matured seeds of kochia plants surviving two applications of Starane Ultra (fluroxypyr) at field-use rate (6.4 fl oz/a) were originally collected from two different corn fields near Garden City, KS, in fall 2017. The progeny seeds of two different accessions (KS-4A and KS-4H) collected from one of these corn fields were used. In addition, seeds of a known susceptible kochia accession (SUS) collected from research fields in Hays, KS, were also used for comparison. Greenhouse experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS. For Aatrex PRE dose-response assays, germination trays (each 10 × 10 inch) containing sterilized field soil were utilized. Experiments were performed in a completely randomized design with four replications (one tray = one replication). Fifty randomly selected seeds from each accession were uniformly spread on the soil surface in each tray. Doses of PRE applied Aatrex, including 0, 1/4X, 1/2X, 1X, 2X, and 4X (1X of Aatrex = 32 fl oz/a) were tested. Emerged kochia seedlings for all three accessions from each tray were counted at 28 days after treatment (DAT). For Aatrex POST dose-response and alternative POST herbicides, separate experiments were conducted using 4- × 4-inch plastic pots containing commercial potting mixture. Kochia plants from SUS and KS-4H accessions were grown and separately treated with POST Aatrex doses (same as mentioned for PRE dose-response assay) along with 1% v/v crop oil adjuvants and alternative POST herbicides. Alternative POST herbicide programs, including Gramoxone, Huskie, Kochiavore, Liberty, Scorch, Sharpen alone or with 2,4-D, Starane NXT, and Talinor were tested at field-use rates

(Table 1). Experiments were conducted in a randomized complete block design with 12 replications. Data on percent visual control (on a scale of 0 to 100; 0 being no control and 100 being dead plant) were recorded at 21 DAT, and individual plants were harvested to determine the shoot biomass at 21 DAT. Data from PRE and POST Aatrex dose-response assays were analyzed using a three parameter log-logistic model in *R* software using following equation (Ritz et al., 2015):

$$y = \{d/1+\exp [b (\log x – \log e)]\} \qquad [1]$$

where y refers to the number of seedlings per tray or shoot biomass (% of untreated), d is the upper limit, b is the slope of each curve, e (also known as ED_{50} or GR_{50} value) is the Aatrex dose required to cause 50% reductions in seedlings emergence (for PRE dose-response) or shoot biomass reduction (for POST dose-response), and x is the Aatrex dose. Resistance factor (referred as R/S ratio) to Aatrex was estimated by dividing the ED_{50} or GR_{50} value of each multiple resistant accession (KS-4A and KS-4H) by the GR_{50} value of SUS accession. Data on percent visual control with alternative POST herbicides were subjected to ANOVA using PROC MIXED in SAS v. 9.3 software (SAS Inst. Inc., Cary, NC). Means were separated using Fisher's protected least significant difference test at $P < 0.05$.

Results

PRE dose-response experiments indicated that the effective dose (ED_{50} values) of PRE applied Aatrex required for 50% reduction in seedling emergence of KS-4A, KS-4H, and SUS was 129, 7, and 1 oz/a, respectively, indicating 129- and 7- fold resistance in KS-4A and KS-4H accessions (Figure 1). In POST dose-response assay, the KS-4H accession exhibited high level (248-fold) resistance to Aatrex, as compared to SUS accession (Figure 2). Among all alternative POST herbicides tested, Gramoxone, Huskie, Talinor, and Sharpen alone or with 2,4-D provided excellent control (94 to 100%) of both SUS and KS-4H accessions. (Table 1). Scorch and Starane NXT treatments provided moderate control (87%) of both accessions at 21 DAT. In contrast, Kochiavore and Liberty treatments provided differential control of SUS (94 to 99% control) and KS-4H (84 to 85%) accessions at 21 DAT (Table 1).

Conclusions

Results indicate that dicamba/fluroxypyr/glyphosate-resistant kochia from Garden City, KS, is also resistant to PRE and POST applied atrazine. Growers can utilize POST herbicides such as Huskie, Talinor, Gramoxone, and Sharpen alone or with 2,4-D to manage this multiple-resistant kochia on their production fields.

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Table 1. Effect of alternative POST herbicides on dicamba/fluroxypyr/glyphosate-resistant and -susceptible kochia in a greenhouse study conducted at the Kansas State University Agricultural Research Center, Hays, KS

Herbicide (s)	Rate	SUS	KS-4H
	fl oz/a	---------------- % control[4]	----------------
Huskie[1]	15	96 aA	98 aA
Kochiavore	16	94 bA	84 bB
Scorch[1]	32	83 cA	79 bcA
Starane NXT[1]	14	85 cA	87 bA
Liberty[2]	36	99 aA	85 bB
Talinor[2]	18	100 aA	99 aA
Sharpen[3]	2	100 aA	100 aA
Sharpen + 2,4-D[3]	2 + 18	99 aA	100 aA
Gramoxone[1]	48	100 aA	100 aA

[1] Nonionic surfactant (NIS) at 0.25% v/v was included.
[2] Crop oil concentrate (COC) at 1% v/v was included.
[3] Methylated seed oil (MSO) at 1% v/v and ammonium sulfate (AMS) at 2% v/v was included.
[4] Means for each kochia accession within a column followed by similar lowercase letters are not significantly different based on Fisher's protected LSD test at $P < 0.05$; means for an herbicide within a row followed by similar uppercase letters are not significantly different based on Fisher's protected LSD test at $P < 0.05$ for % control.

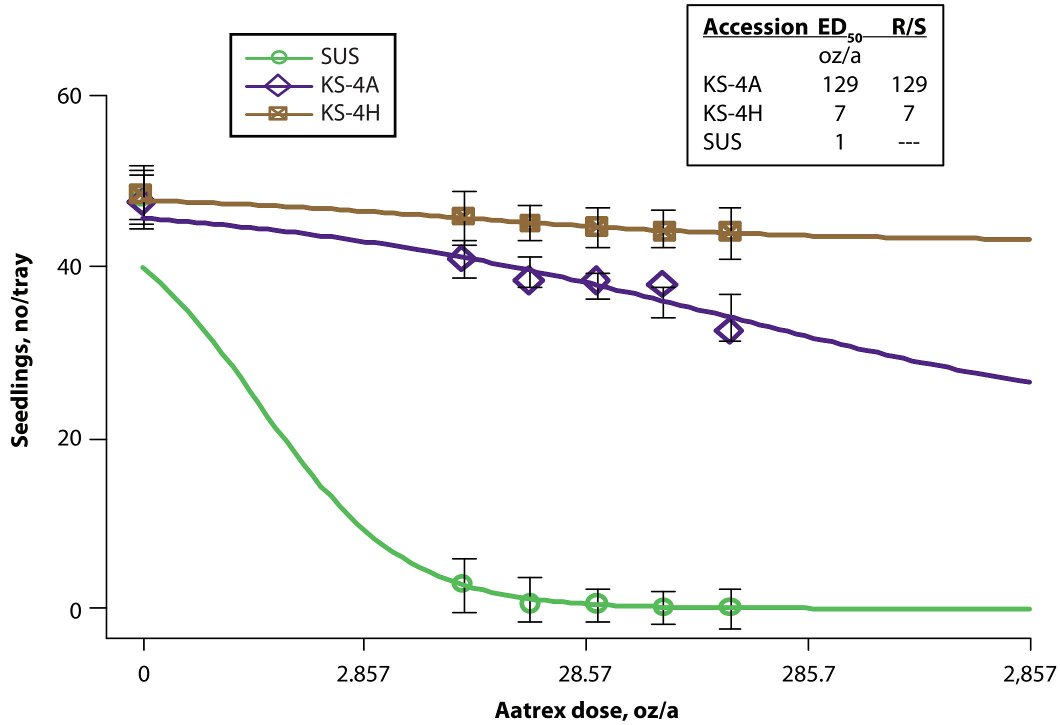

Figure 1. Seedlings emergence of susceptible (SUS) and two dicamba/fluroxypyr/glyphosate-resistant kochia accessions (KS-4A, KS-4H) treated with various doses of Aatrex applied PRE 28 days after treatment (DAT). R/S = resistance factor. ED_{50} is the estimated amount of Aatrex PRE herbicide (oz/a) required to achieve 50% reduction in seedlings emergence of SUS, KS-4A, and KS-4H accessions.

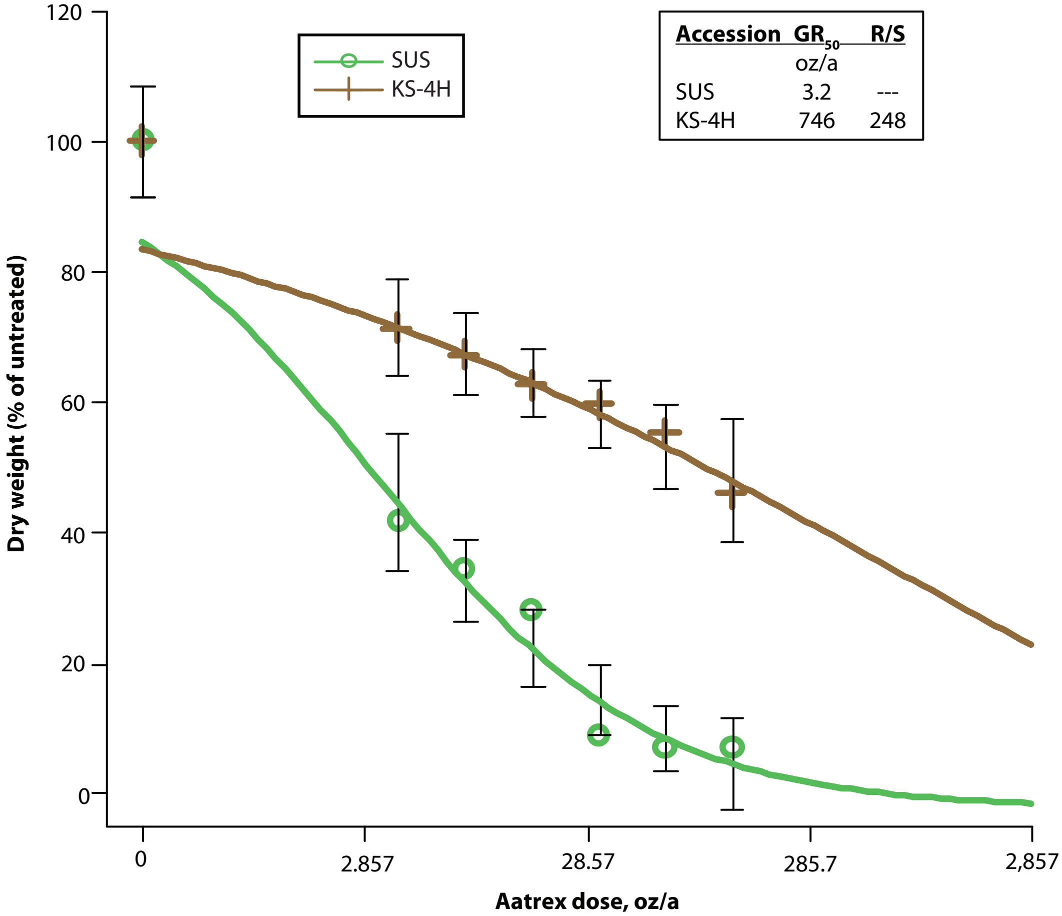

Figure 2. Shoot dry weight (% of untreated) response of SUS and KS-4H kochia accessions treated with POST Aatrex at various doses 21 days after treatment (DAT). R/S = resistance factor. GR_{50} is the estimated amount of POST Aatrex (oz/a) needed for 50% reduction in shoot biomass of SUS and KS-4H kochia accessions.