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Summary

Shattercane is a summer annual grass weed species commonly found in grain sorghum producing regions, including Kansas. Recent development and commercialization of grain sorghum hybrids with tolerance to acetolactate synthase (ALS) and acetyl-CoA-carboxylase (ACCase) inhibiting herbicides will allow producers to use these herbicides for in-season control of shattercane. In a recent field survey, three shattercane populations (DC8, GH4, and PL8) collected from sorghum fields in northwestern Kansas survived the field-use rate (6 fl oz/a) of postemergence (POST) applied IMIFLEX (imazamox). The main objectives of this research were to (1) confirm and characterize the level of resistance to imazamox in those suspected imazamox-resistant (IMI-R) shattercane populations, and (2) determine the effectiveness of alternative POST herbicides for controlling IMI-R shattercane populations. Imazamox dose-response experiments were conducted in greenhouse conditions at the Kansas State University Agricultural Research Center near Hays, KS. A susceptible shattercane population (SUS) collected from sorghum field in Rooks County, KS, was included for comparison. Dose-response analysis revealed that all three populations exhibited a 3.5- to 5.3-fold resistance to imazamox as compared to SUS population. In a field study, POST treatments of nicosulfuron (Zest), quizalofop (Aggressor), clethodim (Select Max), glyphosate (Roundup PowerMax), and glufosinate (Liberty) provided an excellent control (92 to 100%) of IMI-R population at 21 days after treatment (DAT). These results report the first case of imazamox-resistant shattercane in Kansas. Growers should adopt effective alternative POST herbicides tested in this research for managing IMI-R shattercane.

Introduction

Shattercane (*Sorghum bicolor* L.) is one of the most problematic summer annual grass weed species in the sorghum producing region in the Central Great Plains (CGP), including Kansas. Shattercane is closely related to grain sorghum and can exchange genes through crossing and hybridization. If left uncontrolled, season-long infestation of shattercane can cause >95% yield reductions in grain sorghum. Herbicide options for shattercane control in grain sorghum are relatively limited.

Sorghum hybrids (igrowth and Inzen) with tolerance to ALS inhibitors such as imazamox (IMIFLEX herbicide) and nicosulfuron (Zest WDG herbicide) have recently been developed. Both Inzen and igrowth sorghum will allow producers to use POST applications of ALS inhibitors (Zest WDG on Inzen and IMIFLEX on igrowth

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sorghum) for grass weed control. In addition, Double Team sorghum with tolerance to quizalofop-p-ethyl (FirstAct; an ACCase inhibiting herbicide) will also be available for grass weed control. Among these three technologies, the igrowth sorghum has been commercially available, while the other two technologies are in the pipeline. Nonetheless, all three newly developed herbicide-tolerant (HT) sorghum technologies (igrowth, Inzen, and Double Team) will potentially improve the grass weed control options in grain sorghum. Three new HT grain sorghum technologies may be widely adopted soon. A field survey was initiated in the fall of 2019 to determine the response of shattercane populations from the CGP region to ALS and ACCase-inhibiting herbicides. Out of several collections, three shattercane populations (DC8, GH4, and PL8) from northwestern Kansas survived the field-use rate of IMIFLEX (6 fl oz/a) in a preliminary discriminate-dose assay. The main objectives of this research were to (1) confirm and characterize the level of resistance to imazamox in those three putative imazamox-resistant (IMI-R) shattercane populations, and (2) determine the effectiveness of alternative POST herbicides for controlling IMI-R shattercane populations.

Procedures

Field Survey and Greenhouse Screening

A field survey for collection of matured seeds of shattercane was initiated in the fall of 2019 from grain sorghum fields in western Kansas. A total of 30 to 40 populations (40 to 50 seed heads per population) were collected from each field site and were combined to create a composite sample. In preliminary discriminate-dose experiments at the Kansas State University Agricultural Research Center near Hays, KS (KSU-ARCH), three shattercane populations from Decatur (DC8), Graham (GH4), and Phillips (PL8) counties in northwestern Kansas survived ($\leq 65\%$ control at 21 days after treatment) the field-use rate of IMIFLEX (6 fl oz/a). All surviving plants from each population were allowed to grow for seed production in greenhouse conditions and were used in dose-response experiments. In addition to these three putative imazamox-resistant (IMI-R) populations, a shattercane population with known susceptibility to imazamox (IMI-S) was also identified from Rooks County, KS. Plants from all three IMI-R and SUS populations were grown in 4-inch squared plastic pots containing commercial potting mixture. Young seedlings (3- to 4-leaf stage) from each population were separately treated with various doses of IMIFLEX: 0, 1/8X, 1/4X, 1/2X, 1X, 2X, 4X, and 8X, where 1X = field-use rate of IMIFLEX (6 fl oz/a). Data on percent visual injury and shoot dry weights were collected at 21 days after treatment (DAT). Shoot dry weights (% of nontreated) from each population were fitted using 3-parameter log-logistic model in *drc* package in R software using following equation (Knezevic et al., 2007):

$$Y = \{100 / [1 + \exp [b (\log X + \log GR_{50})]]\}$$

where, Y refers to the shoot dry weights (% of nontreated), X is the herbicide dose, GR_{50} is the IMIFLEX dose needed to reduce shoot dry weights of each population by 50%, and b is the slope of each curve.

Field Study

A field study was conducted at KSU-ARCH during summer 2021 to evaluate the efficacy of alternative POST herbicides for managing IMI-R shattercane populations. Seeds of PL8 shattercane population were planted using a 4-row planter in a fallow

field. Experiments were conducted in a randomized complete block design with 4 replications. Eight different POST herbicide programs, including FirstAct (10 fl oz/a), Select Max (16 fl oz/a), Zest WDG (1.33 oz/a), Roundup PowerMax (32 fl oz/a), Liberty (32 fl oz/a), Gramoxone + AAtrex (48 + 32 fl oz/a), Callisto + AAtrex (6 + 32 fl oz/a), and a nontreated weedy check were tested. Data on percent visual control (on a scale of 0 to 100%, where 0 = no control and 100% = complete control) were recorded at 14 and 28 days after treatment (DAT). Data were subjected to ANOVA using PROC Mixed in SAS 9.3 and means were separated using Fisher's protected LSD test at $P \leq 0.05$.

Results

Dose-Response Study

Based on a fitted model, the estimated GR_{50} values (IMIFLEX doses needed for 50% shoot dry weight reduction at 21 DAT) for three putative IMI-R shattercane populations (DC8, GH4, and PL8) ranged from 3.2 to 4.8 fl oz/a while it was only 0.9 fl oz/a for SUS population (Figures 1 and 2). Based on GR_{50} values, all three IMI-R populations exhibited a 3.5- to 5.3-fold resistance to IMIFLEX as compared to SUS population (Figure 1).

Field Study

Results indicated that POST herbicides, including Zest, FirstAct, Select Max, Roundup PowerMax, and Liberty provided an excellent control (92 to 100%) of PL8 shattercane population at 21 DAT (Table 1 and Figure 3). In contrast, a moderate control (85%) of PL8 shattercane population was observed with Gramoxone + AAtrex, while the least control (38%) was observed with Callisto + AAtrex (Table 1).

Conclusions

Results from this greenhouse study indicated that three putative IMI-R shattercane populations from northwestern Kansas had evolved low-level resistance to imazamox. The field study showed an excellent control of PL8 shattercane population with alternative POST herbicides, including FirstAct and Zest WDG. Altogether, these results suggest that Inzen and Double Team sorghum technologies can provide an alternative option for effective shattercane control.

References

Knezevic SZ, Streibig JC, Ritz C (2007) Utilizing R software package for dose-response studies: the concept and data analysis. *Weed Technol* 21:840-848.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Effectiveness of POST herbicides on PL8 shattercane population at 21 days after treatment (DAT)

Herbicide	Rate (oz/a)	14 DAT	21 DAT
FirstAct ¹	10	96 a	98 a
Select Max ²	16	93 a	98 a
Zest WDG ¹	1.33	84 b	92 a
Roundup PowerMax ³	32	100 a	100 a
Liberty ³	32	100 a	100 a
Gramoxone + AAtrex ²	48 + 32	81 b	85 b
Callisto + AAtrex ¹	3 + 32	61 c	38 c
Nontreated	---	---	---

¹Crop oil concentrate (COC) at 0.5% v/v was included.

²Nonionic surfactant (NIS) at 0.25% v/v was included.

³Ammonium sulfate (AMS) at 2% v/v was included.

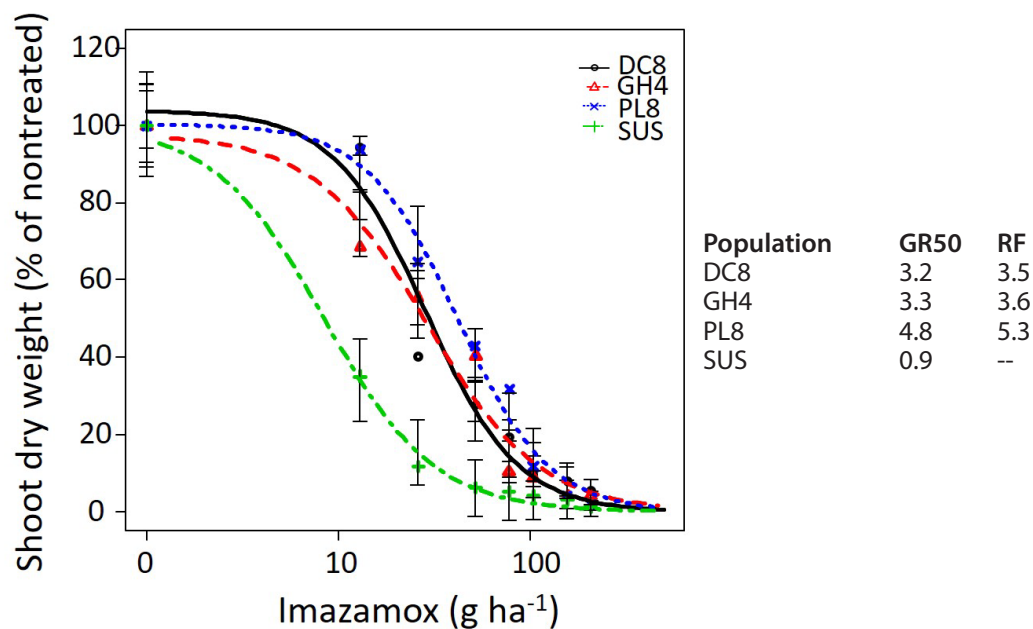


Figure 1. Shoot dry weight (% of nontreated) response of imazamox-resistant and susceptible shattercane population (SUS) to various doses of IMIFLEX herbicide at 21 days after treatment. Populations were collected from three counties in northwestern Kansas: Decatur (DC8), Graham (GH4), and Phillips (PL8).

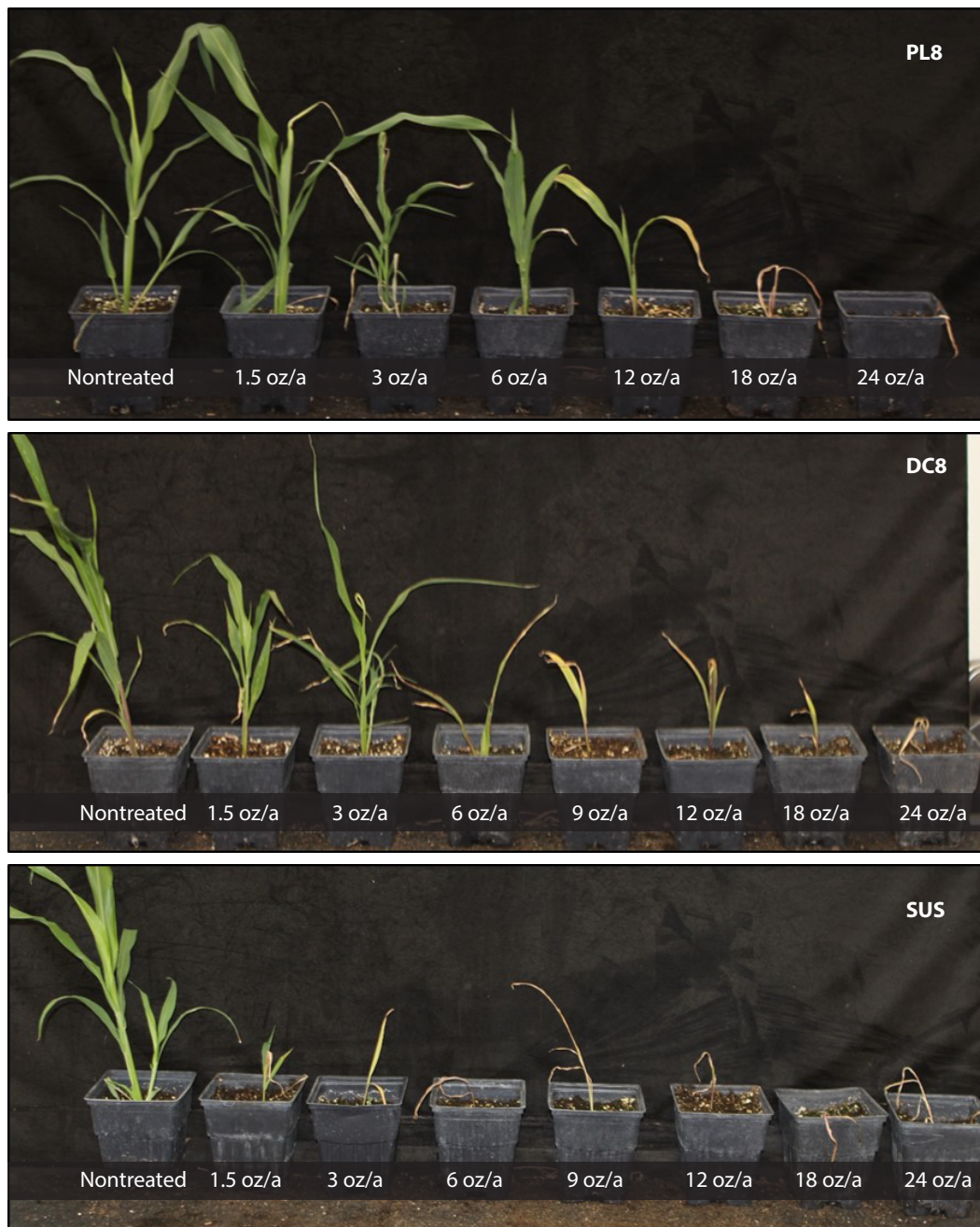


Figure 2. Visual response of imazamox-resistant and susceptible shattercane population (SUS) to various doses of IMIFLEX herbicide at 21 days after treatment. Populations were collected from three counties in northwestern Kansas: Decatur (DC8), Graham (GH4), and Phillips (PL8).



Figure 3. Visual response of the Phillips County, KS, (PL8) shattercane population: nontreated (A) and glyphosate (B) at 21 days after treatment.