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Proso millet is an important short-season summer cereal in western Nebraska, southeast Wyoming, and eastern Colorado. The objective of this study was to evaluate proso millet tolerance to saflufenacil applied early preplant (EPP) or PRE. Field studies were conducted in Lingle, WY and Sidney, NE in 2008 and 2009. A dose–response study was conducted in the greenhouse at the University of Wyoming in Laramie, WY to determine proso millet cultivar response to saflufenacil applied at six rates from 0 to 400 g ai ha^{-1}. In the field, saflufenacil was applied EPP and PRE at 50 and 100 g ha^{-1}. Proso millet stands were reduced by an average of 33 and 23% by PRE and EPP treatments compared with the nontreated check; however, proso seed yields were not affected by saflufenacil timing or rate. In the greenhouse, 'Panhandle' and 'Dawn' exhibited less tolerance to saflufenacil than 'Sunrise', the cultivar used in the field studies.

Nomenclature: Saflufenacil; 2-chloro-5-[3,6-dihydro-3-methyl-2,6-dioxo-4-(trifluoromethyl)-1(2H)-pyrimidinyl[-4-fluoro-N-[[methyl(1-methylethyl)amino]sulfonyl]benzamide; proso millet, *Panicum miliaceum* L.

Key words: Crop injury, herbicide, soil persistence, pre-emergence, preplant, tolerance.

El panicum miliaceum L. es un cereal importante de corta duración en el verano en el oeste de Nebraska, suroeste de Wyoming y el este de Colorado. El objetivo de este estudio fue evaluar la tolerancia del panicum miliaceum L. al saflufenacil aplicado temprano en la pre-siembra (EPP) o PRE. Se llevaron al cabo estudios de campo en Lingle, WY y Sydney, NE en 2008 y 2009. Un estudio de respuesta a la dosis se llevo al cabo en el invernadero en la Universidad de Wyoming en Laramie, WY para determinar la respuesta de los cultivadores del panicum miliaceum L. al saflufenacil aplicado a seis dosis de 0 to 400 g ia/ha. En el campo, el saflufenacil fue aplicado EPP y PRE a 50 y 100 g/ha. Las plantas del panicum miliaceum L. se redujeron en un promedio de 33 y 23% por los tratamientos PRE y EPP en comparación con el testigo no tratado, sin embargo, los rendimientos de la semilla del panicum miliaceum L. no fueron afectados por el tiempo de aplicación o dosis de saflufenacil. Los invernaderos, 'Panhandle' y 'Dawn' mostraron menos tolerancia al saflufenacil que 'Sunrise', éstos cultivares se usaron en estos estudios de campo.

Proso millet is a short-season (45 to 90 d) summer cereal with low water requirements and high water-use efficiencies for both grain and dry matter (Hanna et al. 2004). Proso millet is well adapted for the crop production systems of western Nebraska, southeast Wyoming, and eastern Colorado. In the United States, proso millet is primarily grown for grain (Hanna et al. 2004).

Proso millet grows slowly at first and is a relatively poor competitor with weeds during the first few weeks of growth (Hanna et al. 2004). Weeds can be a major obstacle to proso millet production (Grabouski 1971). Atrazine and propazine have been shown to provide effective residual weed control in proso millet (Anderson 1990; Anderson and Greb 1987; Robinson 1973). However, no triazine herbicide is currently labeled for use in proso millet in the United States. Chemical weed control in proso millet relies on POST-applied herbicides, and many of these herbicides can result in some crop injury.

Grabouski (1971) reported excellent control of redroot pigweed (*Amaranthus retroflexus* L.) in proso millet with POST applications of 2,4-D ester, 2,4-D amine, bromoxynil, and dicamba. Crop injury was observed with all treatments except 2,4-D amine applied at 280 g ai ha^{-1}, but yields were not greatly affected. Despite some early-season injury (< 10%) in 1 of 2 yr, Lyon and Baltensperger (1993) observed no effect of POST applications of bromoxynil, clopyralid, dicamba, or metsulfuron tank-mixed with 2,4-D amine on proso millet grain yield, test weight, seed weight, moisture content, or plant height.

Lyon et al. (2008) observed that although leaves of plants treated with carfentrazone exhibited localized necrosis, leaves emerging after treatment were healthy and grain yields were not affected. Adding carfentazone to dicamba or 2,4-D amine improved control of buffalobur (*Solanum rostratum* Dun.), a noxious weed in several western states. Carfentrazone applied at 18 g ai ha^{-1} improved Russian thistle (*Salsola iberica* Sennen & Pau), kochia (*Kochia scoparia* (L.) Schrad.), and volunteer sunflower (*Helianthus annuus* L.) control when plants were drought-stressed, but did not improve control of these weeds when they were not stressed by drought.

Proso millet growers, particularly those using a no-till system, would like to have a herbicide with soil residual activity that they could apply with their preplant burn-down treatment before planting proso millet. Proso millet grain yields and water use efficiency were increased in a no-till production system compared with a tilled system in eastern Colorado (Anderson 1990). Anderson used atrazine applied in the previous fall or 60 d before planting for effective weed control in the proso millet crop. There are currently no soil-applied herbicides labeled for use in proso millet, which frequently results in the need to apply a POST herbicide for weed control.

Saflufenacil[1] is a new herbicide being developed for preplant burn-down and selective PRE broadleaf weed control in several crops (Grossman et al. 2010). It is classified as a

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pyrimidinedione, which is an inhibitor of protoporphyrinogen oxidase. It has both soil and foliar activity. Saflufenacil reduced biomass of five broadleaf weed species including redroot pigweed and tumble pigweed (*Amaranthus albus* L.) by 82 to 98% when applied PRE at 6 to 30 g ai ha^{-1} (Geier et al. 2009). Sikkema et al. (2008) reported minimal crop injury (1% or less) in several spring small grains to saflufenacil applied PRE at rates up to 100 g ha^{-1}, but unacceptable injury (> 50% 2 wk after application) and yield loss occurred with POST application at the same rates. Similarly, Knezevic et al. (2010) observed no crop injury or yield loss in winter wheat (*Triticum aestivum* L.) with PRE application of saflufenacil up to their highest dose of 400 g ha^{-1}; however, POST applications resulted in significant crop injury and yield reduction, particularly when adjuvants were used. Stahlman et al. (2009) compared tolerance of proso millet, hybrid pearl millet, and foxtail millet to saflufenacil applied PRE and suggested a potential use for saflufenacil in proso millet and pearl millet, but recommended additional studies to define use rates and optimum application times.

The objectives of this study were (1) to evaluate proso millet tolerance to saflufenacil applied early preplant (EPP) or PRE, (2) compare saflufenacil tolerance in proso millet with that observed with commonly used POST herbicides, and (3) determine if proso millet cultivars differ in their response to saflufenacil applied PRE.

Materials and Methods

Field Studies. Field studies were conducted in 2008 and 2009 at the University of Nebraska-Lincoln High Plains Agricultural Laboratory (41°12′N, 103°0′W at 1,320 m elevation) located near Sidney, NE and at the University of Wyoming Sustainable Agriculture Research and Extension Center (42°05′N, 104°23′W at 1,390 m elevation) near Lingle, WY. These two locations are representative of the large range of soil and climate conditions of the northern High Plains. Lingle, WY has shallow soil with high pH and an average annual precipitation of 329 mm. Sidney, NE has deep loam and silt loam soils with moderate pH and an average annual precipitation of 428 mm.

At Sidney, studies were conducted on Keith silt loam soils (Aridic Argiustolls) with a surface soil pH of 7.1 and an organic matter content of 2.3 to 2.8%. At Lingle, studies were conducted on Mitchell silt loam soils (Ustic Torriorthents) with pH of 7.8 to 8.1 and organic matter contents of 3.5 and 2.1% in 2008 and 2009, respectively.

One field study was conducted at each location in each year, for a total of four field studies. The experimental design in all four field studies was a randomized complete block with three replications of each of the 10 treatments. Plots were 3 m wide by 12.2 m long at Sidney and 2.7 m wide by 9.1 m long at Lingle. Proso millet cultivar Sunrise was no-till seeded into winter wheat residues on June 10, 2008 and June 26, 2009 at Sidney and on June 17, 2008 and June 24, 2009 at Lingle. Seeding rate in all four field studies was 17 kg ha^{-1}, and seeding depth ranged from approximately 1.3 to 1.9 cm. Plot areas were treated with glyphosate at 960 g ai ha^{-1} within 5 d before seeding each year. Rows were spaced 25 cm apart at Sidney and 19 cm apart at Lingle.

Herbicide treatments were applied with an all-terrain vehicle-mounted sprayer powered by CO_2 and set to deliver 187 L ha^{-1} at Sidney. At Lingle, herbicide treatments were applied with a CO_2-powered knapsack sprayer delivering 125 L ha^{-1}. EPP treatments were applied 7 to 14 d before seeding and PRE treatments were applied within 1 d after seeding proso millet. Immediately after application of the PRE treatments, 6 to 8 mm of supplemental water was applied through a lateral-move sprinkler irrigation system to ensure activation of the herbicide at Sidney. POST herbicide treatments were applied when proso millet plants were in the two- to five-leaf stage of development. Air temperatures at the time of POST applications ranged from 23 to 26 C, wind speeds were below 16 km h^{-1}, typically less than 8 km h^{-1}, and with the exception of Lingle in 2009, plants were not exhibiting signs of stress.

Proso millet stands were determined in saflufenacil treatments and the nontreated check approximately 2 wk after emergence by counting the number of plants per meter of row at two locations in each plot. A visual estimation of crop injury was made in these same plots using a scale from 0 to 100, with 0 being no injury and 100 being plant death throughout the plot, at approximately 2 wk after seeding. Crop injury was estimated for all treatments 4 wk after POST herbicide applications using the same 0 to 100 scale described above.

Grain yields were obtained by machine harvest, without swathing. Grain weights were adjusted to 12% moisture.

The GLM procedure in SAS was used to obtain ANOVA (Littell et al. 2002). Data were pooled across locations and years when no significant location-by-treatment, year-by-treatment, or location-by-year-by-treatment interactions occurred. If these interactions were significant, then data were analyzed separately by year, site, or both year and site. Means separations were performed using Fisher's Protected LSD at an alpha level of 0.05. Single degree of freedom orthogonal contrasts were used to compare saflufenacil rates and application timings.

Greenhouse Study. A greenhouse study was conducted at the University of Wyoming in Laramie, WY to determine if proso millet cultivars differ in response to saflufenacil. Six proso millet cultivars (Dawn, 'Early Bird', 'Horizon', 'Huntsman', Panhandle, and Sunrise) and one foxtail millet cultivar ('White Wonder') were screened. A foxtail millet cultivar was included in this study because growers often do not differentiate between millet species when seeking herbicide recommendations, and we felt it was important to have a direct comparison of the two species for their tolerance to saflufenacil. Five seeds of each cultivar were planted into 10-cm-diam pots filled with a 2 : 1 sand to potting soil mixture.[2] Saflufenacil was applied immediately after planting at rates of 0, 25, 50, 100, 200, and 400 g ha^{-1}. Each cultivar-by-herbicide dose treatment combination was replicated five times. Emerged plants were counted daily for 2 wk after planting, then weekly until harvest. Crop injury was visually estimated at 10 d after emergence using a scale from 0 to 100, with 0 being no injury and 100 being death of all plants. Plants were harvested at soil level 28 d after treatment and

Table 1. Plant stand 2 wk after emergence, proso millet injury 2 wk after planting, and grain yield after early preplant and PRE application of saflufenacil at two rates at Lingle, WY and Sidney, NE in 2008 and 2009.[a]

Application timing	Rate	Plant stand	Crop injury: Lingle, WY 2008	Lingle, WY 2009	Sidney, NE 2008	Sidney, NE 2009	Grain yield[a]
	g ai ha^{-1}	Plants m^{-1} row	%	%	%	%	kg ha^{-1}
Early preplant (EPP)	50	19.4*	5	13	7	0	2,120
EPP	100	18.3*	10*	20	7	2	2,170
PRE	50	18.0*	6*	27	3	3	2,120
PRE	100	14.6*	15*	62*	38*	5	2,160
Nontreated check		24.4	0	4	0	0	2,050
Significance of contrasts							
EPP vs. PRE		0.021	0.046	0.017	0.014	0.274	0.938
EPP_{50} vs. EPP_{100}		0.478	0.044	0.609	1.000	0.689	0.515
PRE_{50} vs. PRE_{100}		0.031	0.002	0.029	0.001	0.689	0.653

[a] Grain yield data from Lingle, WY in 2009 were not used in the analysis as a result of damage from hail and grasshoppers.

* Significantly different from the nontreated check at P = 0.05.

dried in an oven for 48 h at 60 C. Total plant biomass was divided by the number of plants emerged in each pot to obtain dry weight per plant. Dry weight per plant was divided by the mean dry weight per plant for the nontreated control for each cultivar to obtain the relative dry weight per plant (expressed as a percentage of the nontreated). The experiment was conducted twice. The first run was planted April 22 and harvested June 10, 2009. The second run was planted June 11 and harvested July 29, 2009. No significant interactions with experimental run were observed, so data were combined for analysis.

Analysis of variance was conducted to determine whether the effect of cultivar and saflufenacil rate were significant. Nonlinear regression analysis was then performed on the estimated plant injury and relative dry weight data using the drc package in R (R Development Core Team 2009; Ritz and Streibig 2005). A two-parameter log-logistic regression equation (Equation 1) was chosen after inspection of several models. The two-parameter model is similar to that proposed by Seefeldt et al. (1995) except the upper and lower limits are constrained to be 100 and 0, respectively:

$$f(x) = 100 \Big/ \left(100 + [x/e]^b\right) \quad [1]$$

where $f(x)$ is the response of interest (either plant injury or relative dry weight per plant), x is the saflufenacil rate in g ha^{-1}, e is the inflection point of the fitted line (equivalent to the dose required to cause 50% response [ED_{50}]), and b is the relative slope at the inflection point. Since Sunrise was used in field studies, the ED_{50} of each cultivar was compared with Sunrise using likelihood ratio tests to determine whether those cultivars were more or less tolerant to saflufenacil. Each proso millet cultivar was also compared with the foxtail millet cultivar using the same method.

Results and Discussion

Field Studies. *Saflufenacil Timing and Rate.* The effects of saflufenacil application timing and rate on proso millet stand were similar between locations and years, which allowed the data to be pooled for analysis. Saflufenacil treatments reduced proso millet stand compared with the nontreated check (Table 1). Averaged across rates, proso millet stands were 16% greater following EPP than PRE treatments. Although herbicide rate did not affect plant stand when applied EPP, 19% fewer proso millet plants survived the 100 g ha^{-1} rate than the 50 g ha^{-1} rate when saflufenacil was applied PRE. It appears that crop safety is improved by applying saflufenacil EPP rather than PRE, especially at higher application rates.

Crop injury symptoms evaluated 2 wk after seeding consisted of leaf chlorosis and necrosis, stunting, and stand reduction. Leaf necrosis was generally restricted to the first or second emerged leaves. Later-emerging leaves were mostly unaffected. The effect of saflufenacil application timing and rate on crop injury varied by location and year (Table 1). In three of the four field studies, crop injury was greater with PRE than with EPP treatments. In these same three field studies, greater crop injury was observed when saflufenacil was applied PRE at 100 g ha^{-1} compared with 50 g ha^{-1}. A similar response to rate with EPP treatments was observed only at Lingle in 2008. Crop injury 2 wk after seeding was not affected by treatment at Sidney in 2009. Excellent growing conditions, including a record high 252 mm of precipitation in June, resulted in rapid recovery and growth of proso millet at Sidney in 2009.

Although the relative level of crop injury observed at Lingle in 2009 was greater than that observed at Sidney or at Lingle in 2008, the relative treatment effects of saflufenacil application timing and rate were similar to that observed at Sidney in 2008 (Table 1). Crop injury ratings at Lingle in 2009 may have been confounded by chlorosis symptoms caused by iron deficiency. Proso millet will exhibit symptoms of iron deficiency on soils with pH above 7.8 (Lyon et al. 2008). Although saflufenacil bioactivity increases with increasing soil pH, soil organic matter content has a much greater influence on saflufenacil bioactivity than soil pH (Hixson 2009). Saflufenacil bioactivity decreases as soil organic matter increases. Hixson (2009) recommended that saflufenacil rates be adjusted for both organic matter content and soil textural class. The soil at Lingle in 2009 had the lowest organic matter content of any site (2.1%) and the highest soil pH (8.1). This may partially explain the increased crop injury observed.

Precipitation after application has been suggested as a factor contributing to saflufenacil bioactivity (R. Liebl, personal communication 2010). Precipitation (plus irrigation at Sidney) between the EPP and PRE applications ranged from 0 to 3 mm at Lingle and 46 to 57 mm at Sidney. In the 3 wk after the PRE applications, 11 to 20 mm of precipitation was received at Lingle, compared with 33 and 37 mm at Sidney. Therefore, it is unlikely that precipitation amount or timing had a major effect on differences in proso millet injury observed between years at either location.

The effect of saflufenacil application timing and rate on proso millet grain yield was similar between locations and years, which allowed the data to be pooled for analysis. Grain yield was not affected by saflufenacil treatments. This is similar to the results observed by Soltani et al. (2009) in corn (*Zea mays* L.) and Knezevic et al. (2010) in winter wheat, although no visible crop injury was reported in either study from PRE applications of saflufenacil at rates up to 200 g ha^{-1} in corn or 400 g ha^{-1} in winter wheat. In this study, proso millet plants were able to recover from the early-season stand loss and leaf injury to produce grain yields that were no different from the nontreated check. Previous research on proso millet seeding rates (Nelson 1990; Turgut et al. 2006) were inconsistent regarding the effect of seeding rate on grain yield. Nelson (1990) found numerous interactions of seeding dates, seeding rates, and cultivar types with environment, which suggested that year-to-year weather variation affects the optimal management in any given year.

Grain yield data from Lingle in 2009 was not used in the analysis because of significant hail damage from a storm on August 23 and a late-season grasshopper infestation that was not uniformly distributed across the site. Mean grain yields for saflufenacil treatments and the nontreated check were 716, 2,560, and 3,090 kg ha^{-1} for Lingle in 2008 and Sidney in 2008 and 2009, respectively.

These results suggest that although there is potential to injure proso millet with saflufenacil, particularly when applied PRE at 100 g ha^{-1}, under many conditions proso millet is able to recover from this early-season injury with no effect on grain yield. Stahlman et al. (2009) applied saflufenacil PRE at rates from 36 to 100 g ha^{-1} and noted decreased proso millet stands as saflufenacil rates increased. However, unlike our results, they reported significant yield losses at rates of 50 and 100 g ha^{-1}.

Under adverse growing conditions, such as high soil pH, the ability of proso millet to recover from early-season herbicide injury may be reduced and grain yields may be adversely affected. Unfortunately, we were unable to use the grain yield data from Lingle in 2009 to confirm this speculation, but crop injury symptoms suggested the likelihood of this outcome.

Saflufenacil Compared with POST Herbicides. No treatment differences were observed for crop injury 4 wk after POST herbicide applications at Sidney in either year (data not shown). At Lingle, crop injury 4 wk after POST herbicide applications was observed in both years, with the level of injury observed in 2009 being much greater than in 2008 (Table 2). Crop injury was also more variable at Lingle in 2009 compared with 2008, as demonstrated by the difference in LSD values. As previously mentioned, crop injury ratings at Lingle in 2009 may have been confounded by chlorosis symptoms resulting from iron deficiency in the high-pH soil. Small pockets of healthier-looking proso millet were present throughout the study, and thus visual estimates of crop injury were more variable at Lingle in 2009.

Table 2. Influence of saflufenacil and POST herbicide application on proso millet injury 4 wk after POST applications at Lingle, WY in 2008 and 2009.

Treatment	Timing[a]	Rate	Crop injury 2008	Crop injury 2009
		g ai ha^{-1}	%	%
Saflufenacil	EPP	50	5	17
Saflufenacil	EPP	100	8	53
Saflufenacil	PRE	50	8	67
Saflufenacil	PRE	100	18	93
Carfentrazone	POST	18	7	33
2,4-D amine	POST	561	1	20
Carfentrazone + 2,4-D amine	POST	9 + 421	9	5
2,4-D amine + dicamba	POST	421 + 140	0	20
Prosulfuron + 2,4-D amine	POST	14 + 421	0	17
Nontreated check			0	5
$LSD_{0.05}$			7	26

[a] Abbreviation: EPP, early preplant.

Crop injury at Lingle was greatest in both years when saflufenacil was applied PRE at 100 g ha^{-1} (Table 2). Saflufenacil applied EPP at 100 g ha^{-1} and PRE at 50 g ha^{-1} were the only other treatments that caused significantly more crop injury than the nontreated check in both years. In 2008, carfentrazone + 2,4-D amine also resulted in significantly greater crop injury than the nontreated check, whereas in 2009 carfentrazone applied alone resulted in significantly greater crop injury than the nontreated check. Carfentrazone causes localized leaf necrosis on treated leaves, but new growth is unaffected and injury symptoms become less visible with time (Lyon et al. 2007). Poor crop growth, particularly in 2009, may have extended the length of time that carfentrazone injury was visible.

Grain yields were not affected by herbicide treatments at Lingle in 2008 or Sidney in 2009 (data not shown). Mean grain yields were 733 and 3,190 kg ha^{-1} for Lingle in 2008 and Sidney in 2009, respectively. As previously stated, yield data from Lingle in 2009 were not used. Grain yield differences among herbicide treatments were observed at Sidney in 2008 (Table 3). Although no herbicide treatment resulted in grain yields significantly different from the nontreated check, three POST herbicide treatments, carfentrazone + 2,4-D amine, 2,4-D amine + dicamba, and sulfosulfuron + 2,4-D amine, yielded less than saflufenacil applied PRE at either rate or carfentrazone applied POST.

These results suggest that with the exception of saflufenacil applied PRE at 100 g ha^{-1}, saflufenacil poses no greater risk for crop injury than other herbicides labeled for use in proso millet such as 2,4-D amine, carfentrazone, dicamba, or sulfosulfuron. Proso millet injury from dicamba and carfentrazone has been previously reported (Grabouski

Table 3. Response of proso millet grain yield to saflufenacil and POST herbicides at Sidney, NE in 2008.

Treatment	Timing[a]	Rate	Grain yield
		g ai ha^{-1}	kg ha^{-1}
Saflufenacil	EPP	50	2,450
Saflufenacil	EPP	100	2,510
Saflufenacil	PRE	50	2,600
Saflufenacil	PRE	100	2,730
Carfentrazone	POST	18	2,610
2,4-D amine	POST	561	2,420
Carfentrazone + 2,4-D amine	POST	9 + 421	2,210
2,4-D amine + dicamba	POST	421 + 140	2,170
Prosulfuron + 2,4-D amine	POST	14 + 421	2,230
Nontreated check			2,510
$LSD_{0.05}$			348

[a] Abbreviation: EPP, early preplant.

1971; Lyon et al. 2008). In a few situations, proso millet may recover from early-season crop injury resulting from saflufenacil to produce greater grain yield than when crop injury occurs later in the season as the result of POST herbicide applications.

Greenhouse Study. Significant effects of cultivar and saflufenacil rate were observed with respect to crop injury 10 d after treatment ($P < 0.001$) and relative dry weight per plant 28 d after treatment ($P < 0.001$). Parameter estimates for both injury and dry weight data fitted to Equation 1 are provided in Table 4. All proso millet cultivars were more tolerant to saflufenacil than the foxtail millet cultivar ($P < 0.05$). These results are similar to Stahlman et al. (2009) who reported that the proso millet cultivar Sunrise was more tolerant to saflufenacil in field studies compared with the foxtail millet cultivar 'German Strain R'. When compared with Sunrise, the cultivar used in the field studies, two proso millet cultivars exhibited less tolerance to saflufenacil. Panhandle had a significantly lower ED_{50} with respect to crop injury ($P = 0.013$) (Table 4; Figure 1) and Dawn had a significantly lower ED_{50} with respect to relative dry weight ($P = 0.037$) (Table 4; Figure 2).

These results suggest that although there is some variability in tolerance among proso millet cultivars to saflufenacil, this variability is neither large nor consistent for both crop injury and dry weight reduction. Most modern proso millet cultivars have at least a 25% contribution from Dawn (Baltensperger et al. 1995a,b, 1997, 2004; Nelson 1976), which may limit the range of response to herbicides. Of the cultivars used in this study, only Panhandle, which was released before the other cultivars, has no known relationship to Dawn. Caution may be warranted when planting older proso millet cultivars such as Panhandle after application of saflufenacil. Additionally, all proso millet cultivars were more tolerant to saflufenacil than the foxtail millet cultivar used in this study, and thus it is imperative that this distinction be made when working with growers.

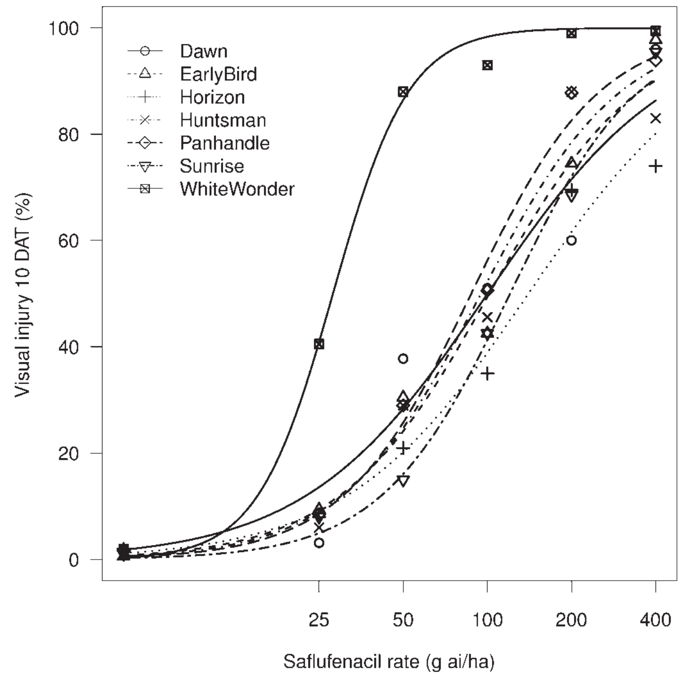

Figure 1. Visual estimate of injury of six proso millet and one foxtail millet (White Wonder) cultivars in response to saflufenacil. Parameter estimates (and standard errors) as described in Equation 1 are provided in Table 4.

On the basis of the results of the field and greenhouse studies, saflufenacil applied at a rate up to 100 g ha^{-1} EPP or 50 g ha^{-1} PRE may be used relatively safely in proso millet. However, it may be prudent to restrict use to soils with a surface pH of < 7.8 to prevent poor crop growth resulting

Table 4. Parameter estimates (with standard errors) for *e*, the inflection point of the fitted line (equivalent to the rate required to cause 50% response [ED_{50}]), and *b*, the relative slope at the inflection point, for crop injury and relative dry weight per plant for six proso millet cultivars and one foxtail millet cultivar.

	Crop injury 10 DAT[a]		Relative dry weight 28 DAT	
Cultivar	*e*	*b*	*e*	*b*
Sunrise	121 (12.6)	−1.9 (0.33)	164 (27.4)	6.2 (4.7)
Dawn	100 (12.9)	−1.3 (0.21)	100 (25.1)*	1.4 (0.53)
Earlybird	102 (11.6)	−1.6 (0.27)	119 (19.5)	2.8 (1.17)
Horizon	140 (18.0)	−1.3 (0.24)	129 (32.0)	1.3 (0.51)
Hunstman	95 (10.5)	−1.7 (0.32)	117 (16.2)	4.0 (2.13)
Panhandle	88 (9.5)*	−1.9 (0.34)	126 (18.8)	4.6 (2.54)
White Wonder (foxtail)	28 (2.3)*	−3.2 (1.01)	22 (5.8)*	2.6 (2.04)

[a] Abbreviation: DAT, days after treatment.

* Denotes an *e* value significantly different from Sunrise at $P = 0.05$.

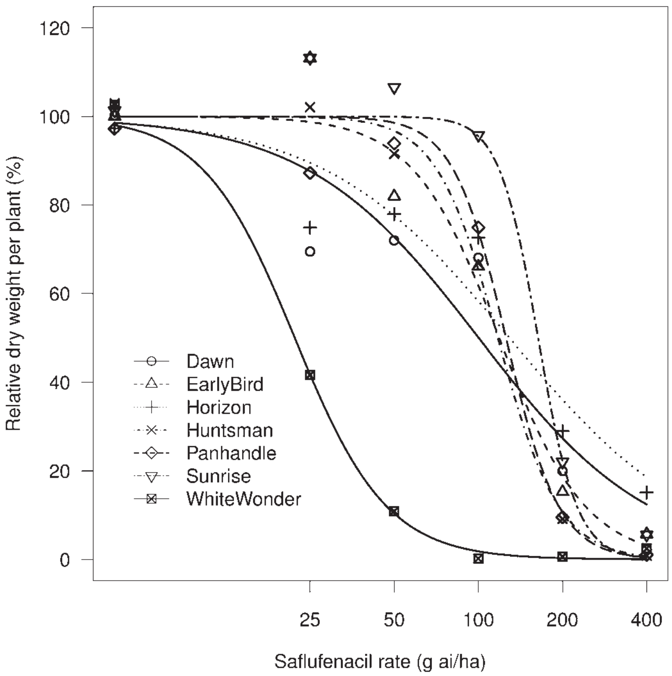

Figure 2. Relative dry weight per plant of six proso millet and one foxtail millet (White Wonder) cultivars in response to saflufenacil. Parameter estimates (and standard errors) as described in Equation 1 are provided in Table 4.

from iron chlorosis to exacerbate injury and prevent rapid recovery from early-season crop injury. Herbicides currently labeled for use in proso millet can only be applied POST and most carry some risk for crop injury. Saflufenacil would provide proso millet growers with an herbicide that may be applied EPP or PRE. This may be an attractive option for no-till production where a burn-down herbicide treatment before seeding is already used.

Knezevic et al. (2009) estimated that 90% control of several broadleaf weeds, including kochia and horseweed [*Conyza canadensis* (L.) Cronq.], required > 200 g ha^{-1} saflufenacil applied alone, but < 80 g ha^{-1} with the addition of methylated seed oil at 1% v/v and < 40 g ha^{-1} when tank-mixed with glyphosate at a rate of 1,100 g ae ha^{-1}. This suggests that saflufenacil, at the rates used in our study, may be used as a preplant burn-down for annual broadleaf weeds with the addition of methylated seed oil or for both broadleaf and grass weeds when tank-mixed with glyphosate. The use of saflufenacil as a preplant burn-down would also provide residual control of broadleaf weeds that emerge after proso millet seeding. This may eliminate the need for a second herbicide application in the growing crop, saving the grower both time and additional application cost.

Sources of Materials

[1] Saflufenacil, BASF Corp., 26 Davis Drive, Research Triangle, NC 27709.

[2] Sunshine SB 300, Sun Gro Horticulture, Vancouver, BC, Canada V7X 1T2.

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