Effect of Herbicide Safeners on Sand and Little Bluestems

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Abstract

Weed competition is a major factor limiting establishment of warm-season grasses. Use of preemergence herbicides in conjunction with herbicide safeners can offer a successful weed control strategy. Effects of herbicide safeners applied as seed treatments, and soil-incorporated herbicides on sand bluestem [*Andropogon gerardii* var. *paucipilus* (Nash) Fern.] and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] were evaluated in germinator and greenhouse studies. The safeners cyometrinil ((Z)- [(cyanomethoxy)imino] benzeneacetonitrile), dichlormid (2,2-dichloro-*N, N*-di-2-propenylacetamide), and R-29148 (2,2-dimethyl-6-methyldichloroacetyloxazolidine) reduced germination and shoot growth of both grasses. Sand bluestem was protected against EPTC (*S*-ethyl dipropyl carbamothioate) and vernolate (*S*-propyl dipropylcarbamothioate) by R-29148, while cyometrinil reduced EPTC damage on little bluestem. Sand bluestem treated with R-29148 tolerated 6 ppm (w/w) of vernolate or EPTC without damage. Without safener treatment sand bluestem was tolerant to metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)-acetamide] (1.25 ppm), vernolate (2 ppm), and cycloate (*S*-ethyl cyclohexylethylcarbamothioate) (2 ppm w/w).

Key Words: ***Andropogon gerardii*** **var.** ***paucipilus*** **(Nash) Fern.,** ***Schizachyrium scoparium*** **(Michx.) Nash, preemergence herbicides, herbicide safeners, germination, dry weight**

Weed control with selective preemergence herbicides could greatly improve warm-season grass establishment (Martin et al. 1982). Atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine], propazine [6-chloro-*N,N'*-bis(1-methylethyl)-1,3,5-triazine-2,4,-diamine], siduron [*N*-(2-methylcyclohexyl)-*N'*-phenylurea], and benefin [*N*-butyl-*N*-ethyl-2,6-dinitro-4-(trifluoromethyl)benzenamine] have shown some potential for selective weed control in warm-season grass seedings (Martin et al. 1982, McMurphy 1969, Ertel et al. 1979).

Limited research has been conducted using herbicide safeners in warm- or cool-season grass seedlings. Orchardgrass (*Dactylis glomerata* L.) was not protected from EPTC (*S*-ethyl dipropyl carbamothioate) and butam [2,2-dimethyl-*N*-(1-methylethyl)-*N*-(phenylmethyl)propanamide] plus cyprazole (*N*-[5-(2-chloro-1,1-dimethylethyl)-1,3,4 thiadiazol-2-yl]cyclopropanecarboxamide) injury when the safeners NA (1,8-naphthalic anhydride) and dichlormid (2,2-dichloro-*N,N*-di-2-propenylacetamide) were used at rates of 0.5, 1.0 and 2.0% (w/w) (Croxford et al. 1975). Safening effect on perennial ryegrass (*Lolium perenne* L.) by NA was more pronounced than dichlormid (Richardson and Kirkham 1982). Of 16 herbicides tested, NA minimized perennial ryegrass injury when treated with alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide], NC 20484 (2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate), MBR 18337 (*N*-[4-(ethylthio)-2-(trifluoromethyl)phenyl]methanesulphonamide), and perfluidone (1,1,1-trifluoro-*N*-[2-methyl-4-(phenylsulfonyl)phenyl]-methanesulfonamide). Similarly, NA protected perennial ryegrass from injury by alachlor, NC 20484, and MBR 18337 (Kirkham et al. 1982). A safener rate of 1.0% (w/w) was optimal. In the greenhouse, Bertges (1976) found treatment of timothy (*Phleum pratense* L.) seeds with NA reduced injury from alachlor, propachlor [2-chloro-*N*-(1-methylethyl)-*N*-phenylacetamide], and EPTC. Whereas, the safeners dichlormid and R-28725 [3-(dichloroacetyl)-2,2-dimethyl-1,3-oxazolidine] did not protect against the same herbicides. However in the field, NA did not protect timothy from any of the herbicides. Coating Kentucky bluegrass (*Poa pratensis* L.) with NA at 5–20% (w/w) provided satisfactory protection in greenhouse and field trials against alachlor and propachlor. Chang et al. (1973) working with the safeners NA, dichlormid, and CDAA (2-chloro-*N,N*-di-2-

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propenylacetamide) found that only NA reduced EPTC toxicity to green foxtail [*Setaria virdis* (L.) Beauv.].

This study evaluated (1) the effect of herbicide safeners on germination of sand bluestem and little bluestem seeds and (2) the ability of herbicide safeners to ensure grass seedling development in soil treated with preemergence herbicides.

Materials and Methods

Germinator and greenhouse experiments were conducted in the summer and fall of 1984. 'Goldstrike' sand bluestem [*Andropogon gerardii* var. *paucipilus* (Nash) Fern.] and 'Camper' little bluestem [*Schizachyrium scoparium* (Michx.) Nash], commonly selected species for revegetation of abandoned cropland in the Nebraska Sandhills, were used in the experiments. Herbicides used were selected based on their efficacy on longspine sandbur [*Cenchrus longispinus* (Hack.) Fern.] a common annual weed on dryland seedings of sandy soil in the Nebraska Sandhills (Kocher 1984, Oldfather 1984). Seeds were debearded in a rubber tumbler to allow easier handling. Prior to seed application the safeners cyometrinil ((Z)-[(cyanomethoxy)imino]benzeneacetonitrile) and dichlormid were mixed with water and R-29148 (2,2-dimethyl-6-methyldichloroacetyloxazolidine) dissolved in butanol. Due to hydrophobic properties of R-29148, methanol is recommended as a solvent. However, preliminary studies comparing different solvents, indicated that butanol was less phytotoxic. Liquid quantities used to treat 100 g of seeds were: 30 ml water for cyometrinil, 20 ml water for dichlormid, and 20 ml butanol for R-29148 (dichlormid and R-29148 are liquid formulations). Following safener application seeds were spread on a polyethylene sheet and dried at 25° C for 12 hours.

Safener Effects on Germination

Experimental units were petri dishes lined with two No. 3 Whatman filter papers on which 25 seeds were placed. Dishes were moistened with 7 ml water which contained 0.1% captan (*N*-[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide), enclosed in polyethylene bags and placed in a germinator. Temperature in the germinator alternated from 35° C for 8 hours (light period) to 25° C for 16 hours (dark period). Safener rates used in percent active ingredient (a.i.) per seed weight were 0.6, 0.9, and 1.2% for dichlormid and R-29148, and 0.7, 1.4, and 2.1% (w/w) for cyometrinil (lowest values represent recommended rates). Germination and shoot length were recorded after at least 60% of the seeds in the control treatments had germinated. Germination period for sand bluestem and little bluestem was 10 and 14 days, respectively. Only seeds with a radicle and a shoot length of at least 1 mm were evaluated. A completely randomized design was used, with each treatment combination including an untreated control replicated 4 times. Treatment effects were evaluated using orthogonal contrasts.

Table 1. Laboratory observations on the effects of three safener rates on germination and shoot length of sand bluestem (SB) and little bluestem (LB) (expressed as percent of untreated control), associated orthogonal contrasts, and coefficient of variation (C.V.).

Safeners	Rate (% w/w)[1]	Germination percent (% of control) SB	LB	Shoot length (% of control) SB	LB
Cyometrinil	0.7	90	74	95	62
	1.4	90	58	95	70
	2.1	88	67	83	66
Dichlormid	0.6	70	58	91	70
	0.9	89	69	82	78
	1.2	36	71	59	86
R-29148	0.6	76	75	104	98
	0.9	81	59	95	86
	1.2	60	64	86	96
C.V. (%)		29	30	14	19
Control vs other		0.05	<0.01	0.07	0.02
Cyometrinil vs other		0.01	—	—	<0.01
Dichlormid vs R-29148		—	—	<0.01	0.02
Dichlormid linear		0.04	—	<0.01	—
Dichlormid quadratic		0.01	—	—	—
R-29148 linear		—	—	0.05	—

[1]Safener per seed weight
[2]PR>F values only shown if <0.10

Seedling Development with Preemergence Herbicides

Polyethylene pots 10.5 cm in diameter, containing a mixture

Table 2. Effects of herbicide safeners[1] and herbicides[2] on plant numbers (% of seed planted) and shoot weight (mg/pot) of sand bluestem (SB) and little bluestem (LB), observed in a greenhouse trial.

Herbicide	Safener	Plant numbers (% of seed planted) SB	LB	Shoot weight (mg/pot) SB	LB
Control	Control	43	26	298	131
	Cyometrinil	34	18	270	68
	R-29148	41	20	331	86
	Dichlormid	37	20	310	81
Metolachlor	Control	40	10	278	18
	Cyometrinil	37	16	295	46
	R-29148	40	14	276	38
	Dichlormid	37	14	239	43
EPTC	Control	42	14	181	26
	Cyometrinil	31	22	156	70
	R-29148	33	14	228	48
	Dichlormid	32	13	199	48
Vernolate	Control	41	13	253	24
	R-29148	38	13	258	36
	Dichlormid	44	15	324	61
Cycloate	Control	44	24	363	96
	R-29148	40	20	348	96
	Dichlormid	31	16	251	71
LSD (0.05%)		7	8	77	40
C.V. (%)		28	39	37	56

[1]Safener rates in % of seed weight (w/w): cyometrinil 0.7, dichlormid 0.6, R-29148 0.6
[2]Herbicide rates in ppm soil (w/w): Metolachlor 1.25, EPTC 2.0, vernolate 2.0, cycloate 2.0

(600 g) of 30% Sharpsburg silty clay loam (Fine montmorillonitic, mesic Typic Argiudoll) and 70% sand were the experimental units. Two trials were conducted to determine the effect (I) of safener and herbicide combinations on sand bluestem and little bluestem seedling development, and (II) of safener and herbicide rates on sand bluestem using the most promising combination based on laboratory experiment and greenhouse experiment I. Herbicides were diluted in water, and poured on the soil contained in a polyethylene bag. Soil and herbicide were mixed thoroughly and transferred to a pot. After sowing (25 seeds per pot at a depth of 5 mm), 100 ml of water containing 0.25% Growmore[1] nutrient mixture (15-35-15 NPK) and 0.05% captan was added to each pot. Pots were surface-irrigated as required during each trial. Greenhouse temperature was maintained at 26±5° C. Plants were clipped to the soil surface at the end of the trial, and oven-dry weight recorded.

Trial I

Safeners were applied at rates of 0.7% a.i. for cyometrinil, and 0.6% (w/w) for dichlormid and R-29148. Metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] at 1.25 ppm, and EPTC, vernolate [*S*-propyl dipropylcarbamothioate], and cycloate (*S*-ethyl cyclohexylethylcarbamothioate) at 2 ppm (w/w) were applied, which are the rates recommended for sandy soils. Cyometrinil, generally recommended as a safener for acetanilide herbicides, was only used with metolachlor and EPTC (expecting other thiocarbamates to respond similar to EPTC). Seeding dates were August 27 and 30 for sand and little bluestem, respectively. The trial was repeated and sand bluestem was seeded September 22 and little bluestem on October 6. Plants were harvested after tiller initiation (35 days and 45 days after planting for sand bluestem and little bluestem, respectively). A completely randomized design with 4 replicates per planting date was used. Results of the 2 trial repetitions were combined for data analysis after testing for homogeneity of variance. The means were compared by least significant difference (LSD) tests ($P<0.05$).

Trial II

The herbicide safener R-29148 was applied to the seed at 0, 0.6, and 1.2% a.i. (w/w). EPTC and vernolate rates of 0, 2, 4, and 6 ppm (w/w) were used. The trial was repeated with sowing dates of September 21 and November 18. Artificial light was provided to maintain a 16-hour daylength. Plants were harvested 40 days after planting. The experiment was designed as a randomized complete block design with 3 replicates. Trial results of the 2 planting dates were tested for homogeneity of variance and combined for data analysis. Orthogonal contrasts were used to compare the treatment effects.

Results and Discussion

Safener Effects on Germination

Treatment means observed for germination and shoot length are presented as percent of the untreated control (Table 1). Variation in germination percentage was high with coefficients of variation of 29 and 30% for sand bluestem and little bluestem, respectively. Safener treatment reduced germination of sand bluestem and little bluestem ($P\leq0.05$ for contrast 'control vs others'). However, with the exception of dichlormid on sand bluestem, there were no differences among rates of safener applied.

All safener treatments reduced little bluestem shoot growth ($P=0.05$ for contrast 'control vs others'), whereas increasing rates of dichlormid and R-29148 had increasing negative effects on the length of sand bluestem shoots ($P<0.05$ linear contrast).

The tolerable upper limit for R-29148 and dichlormid application on sand bluestem appeared to be in the range of 0.6-0.9% a.i. (w/w). Higher rates of cyometrinil possibly could be used, as no difference in germination and shoot growth were found among the rates chosen.

[1]Mention of product names in this paper does not consitute a recommendation by the Nebraska Agr. Exp. Sta.

Seedling Development with Preemergence Herbicides

Trial I

Coefficients of variation were 28 and 37% for germination and 39 and 56% for shoot weight of sand bluestem and little bluestem, respectively (Table 2). Without herbicide application cyometrinil reduced numbers of both sand bluestem and little bluestem ($P<0.05$). Herbicide treatment alone had no effect on number of sand bluestem plants. However, EPTC combined with cyometrinil, R-29148, or dichlormid, and cycloate combined with dichlormid reduced the number of sand bluestem plants. All herbicide treatments except cycloate reduced the number of little bluestem plants ($P<0.05$). Compared to the untreated control, less reduction was observed when cyometrinil was used as a safener for EPTC ($P<0.05$).

Shoot dry weight of sand bluestem generally was not affected by safener treatment without herbicide application, while shoot dry weight of little bluestem was reduced by all 3 safener treatments. Shoot dry weight of sand bluestem was reduced by EPTC. However, with R-29148 as a safener, the shoot dry weight was not different from the untreated control. R-29148 appeared to be the most promising safener for further studies with sand bluestem. Sand bluestem has enough tolerance for the herbicide rates used that safeners were generally not beneficial and an evaluation of their safening effect therefore not possible. All herbicide treatments except cycloate reduced shoot dry weight of little bluestem. Compared to herbicide without safener treatments, little bluestem shoot weights were greater when cyometrinil was used with EPTC.

Trial II

Without herbicide treatment plant numbers and shoot weight were reduced by R-29148 treatment (Figs. 1, 2). However, this

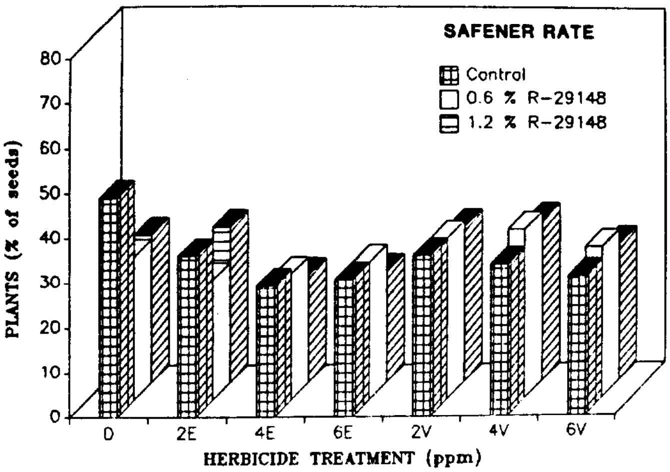

Fig. 1. *Interactions of the herbicide safener R-29148 and the herbicides EPTC (E) and vernolate (V) on the number (in percent of seeds planted) of sand bluestem plants harvested 40 days after planting in a greenhouse trial (Coefficient of variation: 26.1%, herbicide treatment 0 ppm excluded from statistical analysis).*

effect was removed (plant numbers) or reversed (shoot weight) with herbicide application, resulting in a significant herbicide by safener interaction. The herbicide control treatment (0 ppm) was therefore excluded from the statistical analysis.

Safener treatment reduced plant number when averaged over all treatments (Fig. 1, Table 3). Plant numbers were reduced by herbicide treatment, with linear effects significant for both herbicides used. However, safener by herbicide interactions were significant for the EPTC treatment.

Both herbicide treatments reduced shoot dry weights (Fig. 2, Table 3), with linear and linear-quadratic effects significant for EPTC and vernolate, respectively. Safener treatments reduced herbicide injury, regardless of herbicide rate (Contrast 'control vs

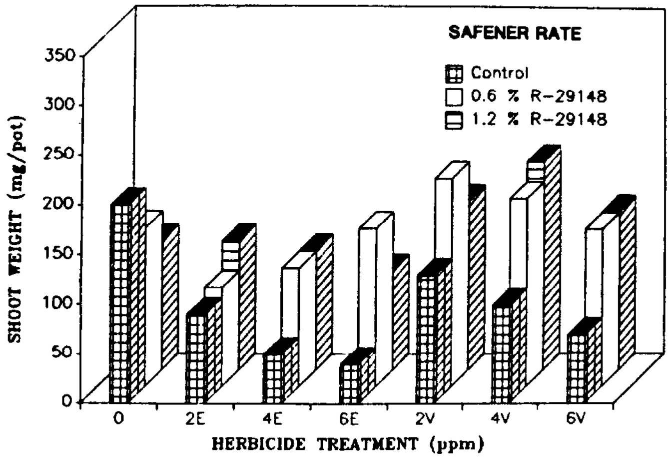

Fig. 2. *Interactions of the herbicide safener R-29148 and the herbicides EPTC (E) and vernolate (V) on the shoot dry weight (mg/pot) of sand bluestem plants harvested 40 days after planting in a greenhouse trial (Coefficient of variation: 44.5%, herbicide treatment 0 ppm excluded from statistical analysis).*

safener' $P<0.01$). Herbicide by safener interactions were significant for contrasts comparing EPTC with vernolate over the safener treatments (control vs safener) and the linear effect of EPTC over the safener treatments. This interaction occurred due to protection against herbicide injury by the safener treatment.

Table 3. Coefficients of variation (C.V.) and PR>F values[1] of orthogonal contrasts comparing the effect of the safener R-29148 and the herbicides EPTC and vernolate on plant numbers (% of seeded) and shoot dry weight of sand bluestem observed in a greenhouse trial.

Categories		Plant numbers	Shoot weight
C.V. (%)		26.1	44.5
Contrasts (PR>F)			
Safeners:	Control vs others	<0.01	<0.01
	0.6% vs 1.2%	—	—
Herbicides:	EPTC vs vernolate	—	0.07
	EPTC linear	<0.01	<0.01
	EPTC quadratic	—	—
	Vernolate linear	0.01	<0.01
	Vernolate quadratic	—	0.03
Interactions:	EPTC vs vernolate in control vs others	<0.01	<0.01
	EPTC linear in control vs others	<0.01	0.09

[1]Only shown if <0.10

The results of the greenhouse experiments suggested that herbicide safeners enhance the selectivity of herbicides used. Protection provided for sand bluestem by R-29148 against EPTC and vernolate was good even at herbicide levels 3 times the recommended field rates. The results further suggested that sand bluestem has a relative high degree of tolerance to metolachlor, vernolate and cycloate. The potential of using the herbicides metolachlor, EPTC, vernolate and cycloate on unsafened sand bluestem seedings and EPTC and vernolate on R-29148 safened sand bluestem seedings merits further research in field trials. Cyometrinil provided the best protection for little bluestem. However, the damage caused by the safener treatment was generally too high to recommend any of the safener and herbicide combinations for field evaluation in little bluestem seedings. Results of the greenhouse experiment largely supported laboratory data for germination, with most of the safener treatments reducing the number of plants present, and little bluestem being more affected than sand bluestem.

Conclusions

Safener treatment reduced germination of sand and little bluestem and shoot length of little bluestem. In greenhouse trials sand bluestem exhibited good tolerance to metolachlor, vernolate and cycloate when used at recommended rates without safener treatment and to EPTC and vernolate when used at 6 ppm (w/w) on R-29148 safened seeds. Cyometrinil reduced EPTC damage on little bluestem. Apparently, none of the herbicide and safener combinations used on little bluestem would have potential for field use while some may enhance the establishment of sand bluestem. However, the high variability of response for sand and little bluestem to preemergence herbicides with and without safeners suggested that the potential of this technique was not clearly defined.

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