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Observations on potential glyphosate tolerance in perennial warm-season grasses

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Observations on potential glyphosate tolerance in perennial warm-season grasses

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KEY WORDS

Conservation Reserve Program, Reclamation, Grama, Old World Bluestem, Panicum, Weeping Lovegrass.

ABSTRACT

An event not expected to be repeated at Tucumcari, N.M., might provide information for research on renovation of weeping lovegrass fields or weed control in other established perennial warm-season grasses. Alkali sacaton (*Sporobulus airoides*), blue grama (*Bouteloua gracillis)*, blue panicgrass (*Panicum antidotale*), kleingrass (*P. coloratum*), old world bluestem (*Bothriochloa ischaemum*) (OWB), sideoats grama (*Bouteloua curtipendula*), switchgrass (*P. virgatum*) and weeping lovegrass (*Eragrostis curvula*) were sown in 1999. Lovegrass established excellent stands within a year; blue grama, kleingrass, sideoats and switchgrass stands were satisfactory in the second year (7, 70, 23, 78, 54, 85, 75, and 95% for sacaton, blue grama, panicgrass, kleingrass, OWB, sideoats, switchgrass, and lovegrass, respectively, least significant difference (LSD, $P < 0.05$) = 19). A glyphosate application to destroy the trial in 2001 reduced lovegrass stands to 20%, while the other species remained unchanged. Perennial warm-season grasses are often difficult to establish. Weed pressure exacerbates this situation. Tolerance to glyphosate would be beneficial in such cases. This, coupled with susceptibility by weeping lovegrass, also may be advantageous for reclamation in problem areas or renovation of CRP fields. Further research is needed to determine appropriate glyphosate application programs to achieve the desired weed control without injury to desirable species.

INTRODUCTION

Perennial warm-season grasses, including native tallgrass prairie species and introduced species, form the basis for summer grazing in irrigated and rainfed pastures throughout the Great Plains of the USA (Coleman et al., 2001; Hudson et al., 2003; Muir et al., 2003; Sanderson et al., 1999). These species are

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well-adapted to semiarid conditions but most are difficult or slow to establish. Exacerbating the establishment problem is competition by weeds (Bovey and Hussey, 1991; Lass and Callahan, 1990). Bovey and Hussey (1991) successfully controlled standing weeds using a ropewick glyphosate application. However, many weeds grow at the same level or below the canopy of the desirable crop, preventing the use of ropewicks. Sanderson et al. (2003), in Pennsylvania, stated that cool-season grasses often invade stands of perennial warm-season grasses, reducing both yield and longevity. They (Sanderson et al., 2003) reported that glyphosate applications in mid-April to newly emerging (5 to 7.5 cm) switchgrass (*Panicum virgatum L.*) had less effect on July hay yields than glyphosate applied in early or mid-May, when the switchgrass was 12.7 to 17.8 cm tall.

With the inception of the Conservation Reserve Program (CRP), approximately 30% of the cropland in the Southern High Plains alone was converted to introduced and native perennial warm-season grasses (Skaggs et al., 1994). In considering the future use of their land, many CRP participants recognized that ranching-based systems are less intensive than row cropping and planned to revert to grazing enterprises when their contracts expired (Skaggs et al., 1994). However, many native species are difficult to establish and seed of those species is expensive. So, much of the CRP land was sown in weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees] as a monoculture or in mixtures with other perennial warm-season grasses, because it is a long-lived perennial that is competitive, easy to establish and productive on a variety of soils (Torell et al., 2000).

Forage production by weeping lovegrass averaged 12.3 Mg ha^{-1} over three years at Tucumcari, while monocultures of flaccidgrass (*Pennisetum flaccidum Gresib.*), indiangrass (*Sorghastrum nutans* (L.) Nash), kleingrass (*Panicum coloratum* L.), and old world bluestem (*Bothriochloa ischaemum* (L.) Keng var. ischaemum) averaged 8.3 Mg ha^{-1} (Kirksey et al., 1993). Sanderson et al. (1999) measured weeping lovegrass and old world bluestem yields of 8.5 Mg ha^{-1} in central Texas. A major limitation to the usefulness of weeping lovegrass in grazing systems is that forage quality declines rapidly when not properly managed (Sanderson et al., 1999; Torell et al., 2000).

An event not expected to be repeated at New Mexico State University's Agricultural Science Center at Tucumcari might provide valuable information to others who are working on problems related to conversion of lands planted to weeping lovegrass or weed control in other established perennial warm-season grasses. The objective of this publication is to report on the establishment rate of selected perennial warm-season grasses and their response to an application of glyphosate when the trial was terminated so that other researchers will have a basis for pursuing the concepts presented herein, if they desire.

MATERIALS AND METHODS

The study was conducted at the New Mexico State University Agricultural Science Center at Tucumcari (35.20° N, 103.68° W; elev. 1247 m) in a field that had been fallow for several years. The soil type was Canez fine sandy loam (Fine-loamy, mixed, thermic Ustollic Haplargid). Each plot was 3.6 x 4.6 m (four 0.9-m furrow beds) with 1.5 m spacing between plots. The test was a randomized complete block with three replications. Planting occurred 6 July 1999, into a conventional tilled seedbed formed into 0.9-m beds for furrow irrigation. Entries included 'Salado' alkali sacaton (*Sporobulus airoides* (Torr.) Torr.), 'Hachita' blue grama (*Bouteloua gracillis* (Willd. Ex Kunth) Lg. Ex

Griffiths), blue panicgrass (*Panicum antidotale* Retz., cv. 'VNS'), 'Selection 75' kleingrass (*P. coloratum* L.), 'WW-Ironmaster' and 'WW-BDahl' old world bluestem (*Bothriochloa ischaemum* (L.) Keng var. *ischaemum*) (OWB), 'Vaughn' sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), 'Blackwell' switchgrass and 'Ermelo' weeping lovegrass. Seed was broadcast by hand on the bed tops only (about 75% of the surface area) and raked-in to increase seed-to-soil contact and to decrease the likelihood of cross-plot contamination during irrigation. Seeding rates were 1.7 kg pure live seed (PLS) ha^{-1} for alkali sacaton and blue grama, 2.3 kg PLS ha^{-1} for kleingrass, 3.4 kg PLS ha^{-1} for OWB and weeping lovegrass, and 5.6 kg PLS ha^{-1} for blue panicgrass, sideoats grama and switchgrass.

Nitrogen (N) fertilizer was applied on 2 July 1999 (56 kg N ha^{-1}), and 13 April (84 kg N ha^{-1}) and 27 July (112 N kg ha^{-1}) 2000. The test was uniformly irrigated on 8, 12, 20, and 27 July, 13 and 26 August, and 14 Sep. 1999, and 27 April, 2 June, 8 July, 24 August, and 18 Sep. 2000. About 200 mm of water were applied with each irrigation and drought stress was never observed. No herbicides were used in 1999. Broadleaf weeds were controlled on 6 May 2000, with an application of 560 g dicamba + 1608 g 2, 4-D acids ha^{-1} in 243 L solution ha^{-1}. Subsequent weeds were controlled with a surface application of 840 g ethalfluralin ha^{-1} in 243 L solution ha^{-1} on 29 June 2000, which was incorporated by 29 mm precipitation the next day. Percentage ground cover was visually rated on 19 Sep. 2000.

On 2 May 2001, 112 kg N ha^{-1} was applied, and the test area was watered on 3 May and 13 June to ensure active growth of all plants prior to application of a nonselective herbicide to terminate the test. On 25 June 2001, the entire test area was treated with 454 g glyphosate acid equivalent in 93.5 L ha^{-1} of a solution also containing 15 g ammonium sulfate L^{-1}. Variability between species in response to the glyphosate application was observed and all plots were rated again on 13 Aug. 2001, for percent ground cover of the planted species, living or dead, as a measurement of living ground cover prior to the glyphosate application, and percent ground cover of living plants, as a measure of survival. It was assumed that plants alive after the glyphosate application had survived the herbicide treatment. Additionally, dead plants were assumed to have been alive before the application, especially since there was an increase in total ground cover from 2000 to 2001. The test irrigated again 26 July 2001, and effectively destroyed with an application of 85 g clethodim in 243 L solution ha^{-1}, on 22 Aug. 2001.

Ground cover date were subjected to SAS GLM procedures for tests of significance for the main effects of species, year [2000 vs. 2001 (living + dead, rated 13 Aug. 2001], and date [before (living+ dead) vs. after (living only) the glyphosate application, both rated 13 Aug. 2001), and interactions between species and year or date (SAS Inst., 2000; Snedecor and Cochran, 1980). Means separation procedures [protected ($P < 0.05$) least significant differences] were used to determine where differences occurred between species for percent ground cover within years or dates.

RESULTS AND DISCUSSION

Percentage stand data collected in the present study are fairly consistent with those measured by Kirksey et al. (1993) at this location for the same species. A significant ($P < 0.0016$) year x species interaction was observed between living ground cover rated in 2000 and 2001 (table 1) such that, within one year, weeping lovegrass rapidly formed nearly complete ground cover. Stands of blue grama were adequate in 2000 and showed modest, though not significant, improvement in the second year (table 1). Kleingrass, OWB, sideoats grama, and switchgrass were slower to establish but ground cover improved in the second year. Alkali sacaton and blue panicgrass began with a low percent ground cover and did not increase significantly in stand over years (table 1).

Muir et al. (2001) found that switchgrass sown in close drills produced less biomass during establishment than switchgrass having wider row spacing. The closer sown switchgrass achieved canopy closure sooner and competed better against weeds than switchgrass in wider rows (Muir et al., 2001). Once the switchgrass was established, the difference in biomass yield due to row spacing recurred in only 1 test year out of 10 (Muir et al., 2001). In the present study, all species were broadcast seeded, which should have aided in competition against weeds that also might have germinated.

The winterhardiness of kleingrass at Tucumcari had been questionable in the past. Lugg and Penaranda (1985), however, reported good performance in southern New Mexico. Additionally, Kirksey et al. (1993) used 'Alamo' switchgrass, which did not survive the first winter (1987-88). However, Blackwell switchgrass was used in the present study; stands of both it and kleingrass increased (table 1) although winter temperatures were less than optimal (Kirksey et al., 2003).

There also was a significant ($P < 0.0001$) date x species in response to the application of 2.5% glyphosate (table 2). Ground cover of weeping lovegrass and blue panicgrass decreased after the herbicide application, while the other species tested survived and flourished. The decrease in blue panicgrass was probably not biologically significant because all of the *Panicum spp.* tested, including blue panicgrass, are sod formers that have extensive root systems with high carbohydrate reserves and are prolific seed producers (Alderson and Sharp, 1995), both of which promote stand regeneration. Blue

Table 1. Percentage ground cover of selected irrigated perennial warm-season grasses sown 6 July 1999, at Tucumcari, NM.

	Rating date		
Species	**19 Sep. 2000**	**13 Aug. 2001†**	**LSD0.05 ‡**
		Ground cover, %	
Alkali sacaton	5	7	ns §
Blue grama	58	70	ns
Blue panicgrass	8	23	ns
Kleingrass	40	78	14
Old world bluestem	41	54	ns
Sideoats grama	30	85	25
Switchgrass	20	75	12
Weeping lovegrass	83	95	8
L.S.D., 0.05	14	19	

† Ratings of sown species were taken 13 Aug. 2001, after a glyphosate application on 25 June 2001. Observations on 13 Aug. 2001, include living and dead ground cover. It was assumed that all plants were alive before the glyphosate application.
‡ Least significant difference at an alpha level of 5%.
§ Not significantly different at P = 0.05.

Table 2. Percentage ground cover of selected irrigated perennial warm-season grasses sown 6 July 1999, taken 13 Aug. 2001 after a glyphosate application at Tucumcari, NM.

	Rating date †		
Species	**Living + dead**	**Living**	**LSD0.05 ‡**
		Ground cover, %	
Alkali sacaton	7	2	ns §
Blue grama	70	68	ns
Blue panicgrass	23	18	<1
Kleingrass	78	78	ns
Old world bluestem	54	41	ns
Sideoats grama	85	80	ns
Switchgrass	75	75	ns
Weeping lovegrass	95	20	57
L.S.D., 0.05	19	20	

† The glyphosate application was meant to terminate the trial. However, because of variability in sown species' response, ratings were taken of living and dead cover on 13 Aug. 2001. Living + dead ratings signify ground cover before the application. The living rating represents those plants not killed by the glyphosate application. Plants that were dead after the application were assumed to have been alive before the application, especially since there was an increase in total ground cover from 2000 to 2001 (see table 1).

‡ Least significant difference at an alpha level of 5%.

§ Not significantly different at P = 0.05.

grama also spreads by stolons, while OWB has a prostrate growth habit that allows it to spread by tillering (Alderson and Sharp, 1995). Blue grama, sideoats grama and old world bluestem are good seed producers as well (Alderson and Sharp, 1995).

Lang et al. (2003) stated that, historically, tallgrass prairie species were harvested to a stubble height of 15 to 20 cm to maintain the growing point and carbohydrate reserves for regrowth. This might be true for some genera (i.e., *Andropogon*, *Schizachyrium*); however, they (Lang et al., 2003) also reported persistence for six years by 'Lometa' indiangrass (*Sorghastrum nutans* (L.) Nash), 'Pete' eastern gamagrass (*Tripsacum dactyloides* (L.) L.), and 'Alamo' switchgrass, but not 'Cave-In-Rock' switchgrass, clipped every 35 to 40 d at a 6.4 to 7.5 cm stubble height.

A belowground mechanism might protect plants from stress and permit regrowth. Duncan and Carrow (1998) described this quality as "root system plasticity." Chandrasena (1990) treated torpedograss (*Panicum repens* L.), another species that develops an extensive root system, with glyphosate and found that single application rates less than 1 kg a.i. ha^{-1} were not sufficient to kill plants >12 wks old, but 8-wk-old plants were controlled. Muir et al. (2001) drilled switchgrass in 18-cm rows and established row-spacing treatments using glyphosate on selected rows followed by hand removal of surviving plants. They did not specify how old the plants were when the glyphosate was applied; however, the presence of survivors indicates some level of resistance by switchgrass to glyphosate (Muir et al., 2001).

The high level of control of weeping lovegrass shows promise for CRP participants and those involved in reclamation of disturbed sites or protecting delicate lands. Weeping lovegrass might be valuable as an early seral species to establish ground cover on highly erodible land. An application of glyphosate could then be used to renovate the area with more desirable species. It is also possible that a seed mixture including glyphosate-tolerant species and weeping lovegrass at a lower seeding rate could be used with a glyphosate application program. One caution is that weeping lovegrass is also a prolific reseeder. White (1991) reported that growth of weeping lovegrass floral stems was effectively controlled with mefluidide. The lovegrass also appears to initiate growth earlier in the spring than the other species tested. So, timing of glyphosate application might be a valuable tool in renovation or reclamation and also worthy of further research.

Chandrasena (1990) reported that, while it took >1 kg ha^{-1} glyphosate to kill established torpedograss in a single application, two split applications totaling 1.5 kg ha^{-1} provided the best control. Chandrasena (1990) also stated that split applications would overcome the possibility of unfavorable environmental conditions during the first application. Species could respond differently to similar environmental conditions, and there could be a differential response between plants within a species depending on individual plant health. In the present study, all species were actively growing without stress when the glyphosate was applied and later when the clethodim was applied. All grass species in the test area were effectively destroyed after the clethodim application. It is possible that once the plants were weakened by first herbicide application and carbohydrate reserves were used for regrowth, there might not be sufficient energy available for regrowth. The subsequent control cannot be attributed strictly to the clethodim application; caution should be taken if using a second application of glyphosate in the same season, because it might be as effective in destroying the stand.

CONCLUSIONS

Resistance to glyphosate would be advantageous for species that are slower to establish such as blue grama, kleingrass, sideoats grama and switchgrass. This, coupled with susceptibility of weeping lovegrass, might also be advantageous for reclamation in problem areas or renovation of CRP fields. Further research is needed to determine appropriate glyphosate application rates to achieve the desired weed control without injury to desirable species. Additionally, application timing, relative to weed and desirable species growth stages, needs to be explored.

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