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Sod-Seeding Perennial Grasses into Eastern Nebraska Pastures¹

John F. Samson and Lowell E. Moser²

ABSTRACT

Eastern Nebraska and neighboring areas have large amounts of depleted pastures which consist of annual brome grasses (*Bromus* spp.), Kentucky bluegrass (*Poa pratensis* L.), and numerous broadleaf weeds. Such pastures need renovation but complete seedbed preparation is expensive and may enhance erosion. The objective of our study was to determine if sod-seeding grasses offered an alternative to complete seedbed preparation. Three weedy pastures in southeast Nebraska on a Hastings silty clay loam (fine, montmorillonitic, mesic Udic Argiustoll), a Lamo silty clay loam [fine-silty, mixed (calcareous), mesic Cumulic Haplaquoll], and a Geary silty clay loam (fine-silty, mixed, mesic Udic Argiustoll) were sprayed with sod suppressing herbicides and sod-seeded with intermediate wheatgrass [*Agropyron intermedium* (Host) Beauv.] or switchgrass (*Panicum virgatum* L.). Spring herbicide treatments consisted of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] plus paraquat (1, 1' dimethyl-4, 4' bipyridinium ion) broadcast and banded at 0.3 + 2.2 kg/ha, respectively, glyphosate [*N*-(phosphonomethyl) glycine] broadcast and banded at 1.1 and 2.2 kg/ha, and paraquat broadcast at 0.3 or 0.6 kg/ha. In the spring experiments both intermediate wheatgrass and switchgrass were seeded. In late summer experiments the atrazine plus paraquat treatments were replaced with banded paraquat and only intermediate wheatgrass was seeded. A nonsprayed but seeded control and a seeded rototilled treatment were included at all locations and dates.

Intermediate wheatgrass stands were acceptable if aboveground herbage suppression was 65% or greater during the first 6 weeks after spraying a subirrigated pasture and 80% or greater during the first 6 weeks after spraying upland pastures in the spring. In order to successfully establish switchgrass complete sod-suppression during the first 6 weeks after spraying was required on the subirrigated pasture and 85% suppression was required on the upland pastures. Glyphosate and paraquat suppressed the sod more severely in late summer but subsequent competition with annual brome increased. Atrazine plus paraquat, or glyphosate broadcast in spring, greatly enhanced the vigor of remnant big bluestem (*Andropogon gerardii* Vitman) in these depleted but unplowed pastures. In some instances the existing big bluestem was dense enough to form a complete stand once the cool-season vegetation was removed. In other situations the seeded switchgrass established around the resident big bluestem clumps.

Additional index words: No-till seeding, Lo-till seeding, Switchgrass, Intermediate wheatgrass, *Panicum virgatum* L., *Agropyron intermedium* (Host.) Beauv., Big bluestem, *Andropogon gerardii* Vitman, True prairie, Atrazine, Glyphosate, Paraquat.

pecially warm-season grasses. In addition, there is a severe erosion hazard with a clean tillage operation. Reducing the number of steps in reseeding may make pasture improvement more acceptable and reduce the erosion risk.

Sod-seeding grass into existing grass communities is not a new concept. Range interseeding, accomplished by catching windblown seed in plowed furrows, was attempted in Texas late in the 19th century (Bentley, 1899). Consequently, the concept of range furrowing has been used for sod-suppression on rangeland for many years. The range interseeder used on fine textured soils in eastern Nebraska has resulted in problems with permanent ridging, poor penetration of equipment and soil crusting in the wide furrow (Schumacher, 1964). Sprague (1952) substituted chemicals for mechanical vegetation control. His work with sodium trichloroacetate (TCA) emphasized the importance of an effective herbicide in sod-seeding. A herbicide used in sod-seeding must give quick, complete control of resident vegetation without leaving residue harmful to emerging seedlings (Sprague, 1960).

The use of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine], glyphosphate [*N*-(phosphonomethyl) glycine], or paraquat (1, 1' dimethyl-4, 4' bipyridinium ion) in sod-seeding perennial grasses has not been investigated extensively in the eastern Great Plains states on depleted pastures such as those in eastern Nebraska. In Canada, paraquat and glyphosphate broadcast at 2.2 kg/ha gave 70% control of a cool-season sod 6 weeks after a June application (Waddington and Bowren, 1976). In England, glyphosphate at 1.0 kg/ha applied in a 7.5-cm band on a cool-season sod improved establishment of Italian ryegrass (*Lolium multiflorum* L.) when compared to paraquat (Squires, 1976). Often interseeded legumes do not require chemical suppression of the sod unless the grass stands are dense and growth is rapid (Taylor et

A PROBLEM with some of the current reseeding techniques for pasture improvement in eastern Nebraska is the relatively long period required to produce a grazable stand of improved perennial grasses, es-

¹ Contribution from the Dep. of Agronomy, Univ. of Nebraska, published with the approval of the Director, Nebraska Agric. Exp. Stn., Journal Series Paper No. 6782. Received 8 Feb. 1982.

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al., 1969) but using a chemical to temporarily suppress the sod may help insure an adequate stand of legume (Olsen et al., 1981). On six cool-season sods in Wales there was 89% desiccation after 2 weeks when glyphosate was broadcast at 1.8 kg/ha in late summer and 86% with paraquat broadcast at 1.1 kg/ha (Cromack et al., 1978). In the same study, rototilling was as effective as herbicides for establishing a grass and legume mix. In Missouri, paraquat broadcast at 1.1 kg/ha in fall suppressed a cool-season sod by 75% and glyphosate broadcast at 2.2 kg/ha gave a 95% reduction in sod cover (Peters and Lowance, 1979).

The objectives of this study were to: a) quantify the suppression of weedy bluegrass (*Poa* spp.) pastures in eastern Nebraska after herbicides were applied, b) compare effectiveness of herbicide treatments on sod suppression in spring or late summer to a clipped sod and a prepared seedbed, c) evaluate impact of the existing vegetation on stand establishment of intermediate wheatgrass [*Agropyron intermedium* (Host) Beauv.] or switchgrass (*Panicum virgatum* L.).

MATERIALS AND METHODS

The experiments were conducted on three deteriorated, native, but unplowed pastures in southeast Nebraska near Beaver Crossing (Seward County) during 1977, 1978, and 1979.

Location I. This experiment was located on a Hastings silty clay loam soil (fine, montmorillonitic, mesic Udic Argiustoll). This pasture had an approximate botanical composition of 60% Kentucky bluegrass (*Poa pratensis* L.), 30% tallgrass prairie remnants, primarily big bluestem (*Andropogon gerardii* Vitman), and 10% annual grasses and forbs.

Treatments were applied to the sod which was mowed to 4 cm (Table 1). All herbicides were applied in 373 liters/ha of water to 3.0 × 7.6 m plots. Broadcast treatments were applied with a plot sprayer 24 hours before seeding. At this time, rototilled treatments were tilled to a depth of 8 to 10 cm and then cultipacked.

The experimental design was a split plot with three replications. Seeded grasses were main plots and subplots were the 10 sod suppression treatments. 'Pathfinder' switchgrass and 'Slate' intermediate wheatgrass were sod-seeded at 5.1 and 21.3 kg Pure Live Seed (PLS)/ha, respectively (370 PLS/m²). Plots were seeded on 25 Apr. 1977 with one pass (2.4 m) of a modified John Deere 1500 Powr-Till³ seeder. The modified seeder had spring-loaded press wheels, rear soil flaps, and drag chains to improve seed coverage. Cutter blades were set to make a 3-cm deep groove with a 1 to 2 cm fillback of soil and mulch. Banded herbicide treatments were sprayed in front of the cutters in a 10-cm band over rows spaced 20 cm apart treating 50% of total area. Herbicide rates refer to the rates within the banded area.

No fertilizer was applied at seeding. Intermediate wheatgrass blocks were fertilized 7 Sept. 1977, with 56 kg/ha of N (33-0-0) and again on 21 Sept. 1978. Phosphorous was applied at 9.5 kg/ha P (0-46-0) on 7 Sept. 1977 since the soil test indicated low P.

In this experiment aboveground living herbage (residual herbage) was clipped to assess sod suppression at 3 and 9 weeks after seeding. Three 0.14 m² quadrats were clipped at soil level in each plot and oven dried (70 C) to a constant weight. Previously clipped areas were avoided at later sampling dates. All plots were uniformly mowed to 8 cm and excess material was removed after the 9-week biomass har-

vest. Three weeks later plots were clipped again to 8 cm to further suppress competition.

Stands of seeded grasses were evaluated at the end of the first growing season and again the following spring. Frequency of seeded grass plants was determined on four 0.9 m lines per plot. Stands were evaluated by determining the percent of 5-cm row segments that contained one or more seeded plants. If 10% or more of the segments were occupied with the seeded species, it was considered an acceptable stand. This acceptance level is approximately equal to 10 or more seedlings/m² which was considered to be a good grass stand by the Great Plains Agricultural Council (Launchbaugh, 1966). A 0.9 × 5.8 m strip was harvested in each plot to determine forage yield in June and August 1978.

Location II. These experiments were located on a Lamo silty clay loam [fine-silty, mixed (calcareous), mesic Cumulic Haploquoll]. This subirrigated pasture had a mixture of approximately 60% Kentucky bluegrass, 10% redtop (*Agrostis alba* L.), 10% timothy (*Phleum pratense* L.), 10% white clover (*Trifolium repens* L.), and 10% annual grasses and forbs.

Spring sod suppression treatments were applied as on Location I. In the late summer seeding (28 Aug. 1977), only intermediate wheatgrass was seeded so atrazine plus paraquat was deleted as a treatment and paraquat treatments banded at 0.3 and 0.6 kg/ha were added (Table 2). The experimental design of the spring seeding on 13 Apr. 1978, was identical to that in Location I. A severe annual brome (*Bromus* spp.) invasion occurred within 2 weeks after seeding on the August 1977 experiment so propanil (isopropyl *N*-phenylcarbamate) was broadcast at 2.2 kg/ha on one-half of each plot on 2 Dec. 1977, when the soil was frozen. Since there was no significant difference ($P < 0.05$) in intermediate wheatgrass stand frequencies due to the propanil treatment, stand counts from nontreated and propanil-treated areas were combined for analysis.

In the late summer seeding, sod suppression was measured 3 and 6 weeks after the treatments were applied with methods as in Location I. The residual herbage harvests for the April 1978 seeding were taken 3, 6, and 9 weeks after seeding. Switchgrass and intermediate wheatgrass stand frequencies and yields were measured as in Location I. All intermediate wheatgrass blocks were fertilized 21 Sept. 1978 and on 19 Sept. 1979, with 56 kg/ha of N (33-0-0). Switchgrass blocks were fertilized 15 June 1979, with 56 kg/ha of N (33-0-0). Soil test results indicated that P was not required at Location II.

Location III. These experiments were located in a third pasture on a Geary silty clay loam (fine-silty, mixed, mesic Udic Argiustoll). This upland pasture had a mixture of approximately 60% Kentucky bluegrass and Canada bluegrass (*Poa compressa* L.), 20% tallgrass prairie remnants predominantly big bluestem, and 20% western wheatgrass (*Agropyron smithii* Rydb.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex. Steud.], and forbs.

The experimental designs were identical to those at Location II. The late summer seeding was planted 30 Aug. 1978. The spring seeding broadcast herbicide and tillage was planted on 12 May 1979, 2 weeks after treatments due to rain and previous drill commitments. Residual herbage harvests, stand frequencies, and forage yields were measured as in Location II.

Botanical composition was measured on 2 Oct. 1979 with a modified single point intercept technique (Owensby, 1973). Three points were widely spaced in a standard 10-point frame to avoid duplication. The closest basal plant was recorded in a 180° arc in front of the point and 108 points were recorded per plot.

August 1978 and May 1979 seeded intermediate wheatgrass blocks were fertilized 19 Sept. 1979, with 56 kg/ha of N (33-0-0) and 14.6 kg/ha of P (0-46-0).

³ Mention of trade name does not imply endorsement of the product or company.

Table 1. The effects of method of herbicide application, herbicide rate, and tillage on vegetation suppression as measured by residual herbage yields and subsequent establishment of intermediate wheatgrass. Seeding was made at Location I on 25 Apr. 1977, near Beaver Crossing, Nebr.

Herbicide or tillage	Method	Rate	Residual herbage at 3 weeks	Stand frequency†	
				Intermediate wheatgrass	% of 5-cm row segments occupied
		kg/ha			
Control	--	--	1,200 a*	2.3 c	
Glyphosate	Band	1.1	1,100 a	3.5 c	
Paraquat + Atrazine	Band	0.3 + 2.2	1,070 a	0.5 c	
Glyphosate	Band	2.2	1,050 a	0.7 c	
Paraquat	Bcst‡	0.3	824 b	4.6 c	
Paraquat	Bcst	0.6	595 c	6.2 c	
Paraquat + Atrazine	Bcst	0.3 + 2.2	557 c	0.4 c	
Glyphosate	Bcst	2.2	293 d	49.8 a	
Glyphosate	Bcst	1.1	287 d	35.4 b	
Rototilled	--	--	18 e	55.3 a	

* Means in columns followed by a common letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

† Stand frequencies are the average of counts taken 6 and 12 months past seeding.

‡ Broadcast.

The data in all experiments were analyzed with an analysis of variance and Duncan's Multiple Range Test was used to separate the treatment means. Orthogonal contrasts were used to compare banding vs. broadcasting and herbicides.

RESULTS

Location I. The herbicides provided initial vegetation suppression but there were no differences in residual herbage yield 9 weeks after spraying. Although residual herbage was measured up to 9 weeks after herbicide application, data at 3 weeks was used in evaluating competition. Glyphosate and paraquat plus atrazine provided excellent control of cool-season vegetation so warm-season prairie remnants that were present grew very rapidly and were responsible for most of the residual herbage yield 9 weeks after application.

Intermediate wheatgrass established satisfactorily in the rototilled and glyphosate treated plots (Table 1). The frequency of intermediate wheatgrass plants increased markedly when residual herbage was suppressed to less than 300 kg/ha at 3 weeks after seeding. Neither broadcast paraquat nor any banded herbicide suppressed vegetation below 300 kg/ha at 3 weeks. Paraquat plus atrazine damaged intermediate wheatgrass seedlings as previously reported by Eckert et al. (1972).

There were no significant differences in dry matter yields of intermediate wheatgrass harvested 5 June 1978, or regrowth harvested 6 Sept. 1978 (data not shown). Overall means were 1,800 kg/ha for the June harvest and 2,660 kg/ha for the September harvest. Apparently, suppressed sods had recovered after 1 year or had seeded intermediate wheatgrass contributing to yield. Although the switchgrass had a satisfactory germination test, seedlings failed on all plots due to low seed vigor.

Location II. Herbicides suppressed vegetation in

Table 2. The effects of method of herbicide application, herbicide rate, and tillage on vegetation suppression as measured by residual herbage yields and subsequent establishment of intermediate wheatgrass or switchgrass. Seedings were made at Location II near Beaver Crossing, Nebr.

Date applied and herbicide or tillage	Method	Rate	Residual herbage at 6 weeks	Stand frequency†	
				Int. wheatgrass	Switchgrass
		kg/ha			
				% of 5-cm row segments occupied	
28 Aug. 1977					
Glyphosate	Band	2.2	3,240 a*	13.9 cd	--
Control	--	--	3,120 ab	12.7 cd	--
Paraquat	Band	0.3	2,970 abc	8.8 d	--
Glyphosate	Band	1.1	2,880 abc	21.1 bcd	--
Paraquat	Band	0.6	2,700 bc	13.4 cd	--
Paraquat	Bcst‡	0.3	2,570 cd	28.5 ab	--
Paraquat	Bcst	0.6	2,200 d	22.0 bc	--
Glyphosate	Bcst	1.1	2,190 d	28.7 ab	--
Glyphosate	Bcst	2.2	2,160 d	35.6 a	--
Rototilled	--	--	2,060 d	14.6 cd	--

11 Apr. 1978

Control	--	--	3,220 a	0.2 d	0.2 b
Glyphosate	Band	1.1	2,890 ab	0.5 d	0.2 b
Paraquat + Atrazine	Band	0.3 + 2.2	2,790 ab	0.2 d	1.4 b
Glyphosate	Band	2.2	2,540 b	1.4 d	0.2 b
Paraquat	Bcst	0.3	1,970 c	2.1 d	0.9 b
Paraquat	Bcst	0.6	1,170 d	11.8 c	2.1 b
Rototilled	--	--	497 e	12.5 bc	0.7 b
Glyphosate	Bcst	1.1	87 ef	21.5 a	5.6 b
Glyphosate	Bcst	2.2	62 ef	18.1 ab	7.4 b
Paraquat + Atrazine	Bcst	0.3 + 2.2	32 f	0.5 d	30.3 a

* Means in columns, within a date, followed by a common letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

† August stand frequencies are the average of 2.2 kg/ha propanil and non-treated split plots taken 15 months past seeding. April stand frequencies are the average of counts taken 6 and 12 months past seeding.

‡ Broadcast.

the late summer seeding similar to the spring treatments. Plants appeared to initiate leaf chlorosis 1 week earlier when treated with glyphosate in late summer compared to spring treatments. A severe annual brome stand was evident 2 to 3 weeks after seeding intermediate wheatgrass. The high residual herbage yield on rototilled plots at 6 weeks was predominately annual brome growth (Table 2). Intermediate wheatgrass established satisfactorily in all treatments except banded paraquat at 0.25 kg/ha. Frequency of intermediate wheatgrass plants was generally twice as great with broadcast compared to banded herbicides. An orthogonal comparison indicated that glyphosate was more effective than paraquat. Dry matter yields of seeded and chemically suppressed plots harvested 4 June 1979 were significantly greater ($P < 0.05$) than plots that were seeded without vegetation suppression (4,760 compared to 3,880 kg/ha) (data not shown). Broadcast herbicides compared to banding improved yield by 53% (5,750 kg/ha compared to 3,760 kg/ha).

In the spring seeding, glyphosate and paraquat plus atrazine provided effective sod suppression since there were less warm-season grass remnants than at Location I. Broadcast paraquat plus atrazine was significantly more effective than glyphosate broadcast 1.1 and 2.2 kg/ha in controlling residual herbage at 9

weeks after application because annual weeds and white clover were controlled. Glyphosate broadcast at 1.1 and 2.2 kg/ha was still as effective as rototilling for sod suppression 6 weeks after treatment (Table 2). A satisfactory stand of switchgrass occurred only with the broadcast paraquat and atrazine treatment (Table 2). Intermediate wheatgrass established with glyphosate broadcast at 1.1 and 2.2 kg/ha as it did at Location I. Paraquat broadcast at 0.6 kg/ha and ro-

totilling were equally effective for establishment, however, stands were only two-thirds as great as was obtained with broadcast glyphosate. Banded herbicides again were not as effective as broadcast treatments. A major botanical shift to white clover was observed on the broadcast glyphosate plots and increased resident white clover was very competitive with intermediate wheatgrass. White clover resistance to glyphosate in spring applications has previously been reported by Oswald (1976).

Location III. In the late summer seeding, sod suppression treatments were consistent with late summer seeding results at Location II but annual brome competition was much less severe. Intermediate wheatgrass established satisfactorily in all treatments except the nonsuppressed control (Table 3). Intermediate wheatgrass frequency was 1.6 times greater with broadcast compared to banded herbicides. The highest frequency of intermediate wheatgrass was on the broadcast glyphosate and rototilled plots.

In the spring seeding, the herbicide treatments suppressed vegetation similar to the other locations. The least sod suppression was measured with the banded herbicides and broadcast paraquat was intermediate for vegetation suppression. The broadcast glyphosate and the broadcast paraquat plus atrazine suppressed the sod the most at 6 weeks (Table 3). The 2-week time lapse between broadcast herbicide and tillage treatments and seeding increased competition with the seedlings. Switchgrass established satisfactorily in the rototilled and broadcast herbicide treatments except paraquat broadcast at 0.3 kg/ha (Table 3). Intermediate wheatgrass established only in rototilled and glyphosate broadcast at 1.1 and 2.2 kg/ha treatments which was consistent with other spring locations.

Dry matter yields were taken the seeding year on 2 Oct. 1979. Plots where glyphosate or paraquat plus atrazine were broadcast yielded about seven times more than plots where herbicides were not applied (Table 4). This rapid increase in productivity resulted largely from the contribution of resident warm-season perennial grasses (P-WSG, Table 4), primarily big bluestem. Although resident vegetation was sampled just one time, the striking differences between cool- and warm-season grass populations are definite. This phenomenon also was observed at Location I. The broadcast paraquat plus atrazine combination was particularly effective for regenerating resident warm-

Table 3. The effects of method of herbicide application, herbicide rate, and tillage on vegetation suppression as measured by residual herbage yields and subsequent establishment of intermediate wheatgrass or switchgrass. Seedings were made at Location III near Beaver Crossing, Nebr.

				Stand frequency†	
Date applied and herbicide or tillage	Method	Rate	Residual herbage at 6 weeks	Int. wheat-grass	Switch-grass
			kg/ha	% of 5-cm row segments occupied	
28 Aug. 1978					
Glyphosate	Band	1.1	820 a*	13.2 cd	--
Gyphosate	Band	2.2	790 a	14.1 cd	--
Control	--	--	722 a	7.2 d	--
Paraquat	Band	0.3	694 a	24.5 bc	--
Paraquat	Band	0.6	678 a	21.3 c	--
Paraquat	Bcst‡	0.6	370 b	20.1 cd	--
Paraquat	Bcst	0.3	316 bc	20.6 cd	--
Glyphosate	Bcst	2.2	223 bc	39.6 a	--
Glyphosate	Bcst	1.1	203 bc	35.6 ab	--
Rototilled	--	--	113 c	38.9 a	--
27 Apr. 1979§					
Glyphosate	Band	2.2	2,160 a	0.0 c	1.4 b
Control	--	--	2,150 a	0.5 c	3.3 ab
Paraquat + Atrazine	Band	0.3 + 2.2	1,880 a	0.0 c	2.3 ab
Glyphosate	Band	1.1	1,880 a	0.0 c	6.5 ab
Paraquat	Bcst	0.3	1,140 b	0.0 c	5.6 ab
Paraquat	Bcst	0.6	841 b	0.0 c	13.4 ab
Rototilled	--	--	404 c	13.4 ab	17.1 ab
Glyphosate	Bcst	1.1	366 c	15.3 a	12.5 ab
Paraquat + Atrazine	Bcst	0.3 + 2.2	358 c	0.0 c	17.6 ab
Glyphosate	Bcst	2.2	321 c	9.7 b	22.2 a

* Means in columns, within a date, followed by a common letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

† August stand frequencies are the average of 2.2 kg/ha propanil and non-treated split plots taken 15 months past seeding. April stand frequencies are the average of counts taken 6 and 12 months past seeding.

‡ Broadcast.

§ Seeding and banded herbicide treatments were delayed 2 weeks until 12 May 1979 due to rain and previous drill commitments.

Table 4. The effects of method of herbicide application and herbicide rate on botanical composition and dry matter production at Location III, 2 Oct. 1979. Herbicides were applied on 27 Apr. 1979.†

Herbicide	Method	Rate	Composition‡					Dry matter yield
			P-WSG	P-CSG	A-CSG	Sedge	Forbs	
		kg/ha	%					
Control	--	--	17.6 b*	71.6 a	2.4 a	2.8 b	5.0 b	437 c
Glyphosate	Bcst§	1.1	36.1 ab	27.5 b	8.3 a	4.6 b	23.5 a	2,200 b
Glyphosate	Bcst	2.2	63.6 a	3.4 c	4.9 a	5.0 b	22.3 a	2,760 b
Paraquat	Bcst	0.6	19.7 b	63.0 a	4.6 a	7.4 ab	4.7 b	977 c
Paraquat + Atrazine	Bcst	0.3 + 2.2	61.1 a	13.2 bc	4.3 a	15.4 a	4.3 b	3,890 a

* Means in columns followed by a common letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

† Botanical composition and dry matter yields taken only on switchgrass seeded replicates.

‡ P-WSG = perennial warm-season grasses, P-CSG = perennial cool-season grasses, and A-CSG = annual cool-season grasses.

§ Broadcast.

season perennial grasses and establishing seeded switchgrass. The seeded switchgrass established around the expanded plants of big bluestem. The increase in forbs in the glyphosate plots was largely due to annuals.

DISCUSSION

The critical period for reduction of competition for intermediate wheatgrass and switchgrass is during the seedling stage. Competition from resident plants must be virtually removed in order to establish new grass seedlings. Intermediate wheatgrass stands were generally acceptable ($>10\%$ frequency) if residual herbage was suppressed by 65% or more on the subirrigated site and by 80% or more 6 weeks after application on both upland sites in the spring. Reduction of competition was especially critical for switchgrass establishment. In order for switchgrass to establish on the subirrigated site it was necessary to completely control residual herbage for 6 weeks and it was necessary to have an 85% or greater reduction of residual herbage on the upland site 6 weeks after seeding. Sprague et al. (1962) stated that growth and development of seeded sudangrass [*Sorghum sudanense* (Piper) Stapf.] in unsuppressed bluegrass sods was unaffected until 10 days after emergence. In our studies rototilling, glyphosate, or paraquat plus atrazine were advantageous because they provided a longer period of reduced competition for emerged seedlings.

Banding herbicides allowed surviving vegetation to tiller with increased vigor, thus resulting in competition with the seeded grasses. Apparently, banded herbicides generally did not reduce competition from residual vegetation enough to allow grass seedling establishment. Since dust deactivates glyphosate and paraquat (Allen, 1966), banded herbicides do not permit successful establishment of seeded grasses under dusty conditions. Applying these two herbicides at

time of seeding on dry soils will not be satisfactory when using seeders which create dust.

Fall applied herbicides appeared to act faster and reduce competition longer compared to spring applications. The action of glyphosate appeared to be enhanced when the plants were translocating a major portion of photosynthates to roots and rhizomes in late summer. This observation corresponds with that of Sprinkle et al. (1975) and Whitwell and Santelmann (1978).

If conditions are suitable annual cool-season grasses may establish rapidly in suppressed areas in the fall and compete severely with seeded vegetation. On the subirrigated site clipping was required in the fall after late summer seeding and again the following spring to retain seeded intermediate wheatgrass. Klingman and McCarty (1958) demonstrated that 2 years of clipping in June was effective in decreasing annual bromes in similar pastures. Propham applied in December to intermediate wheatgrass appeared to provide some control of annual brome, however, after 15 months intermediate wheatgrass stands with propham were similar to stands obtained with clipping alone.

Sod-seeding intermediate wheatgrass may result in a mixture of improved and resident cool-season perennial grasses if the sod is not killed. The resulting mixture is difficult to manage in order to allow the seeded grass to dominate. Intensive postseeding management with use of fertilizer and rotational grazing or timely clipping would be required for seeded cool-season grasses to thicken and dominate in subsequent growing seasons. Often, the time required to obtain a complete stand is prolonged so the use of prepared seedbeds may be easier and faster than sod seeding for cool-season grass establishment if erosion is not too great a risk.

Atrazine will generally suppress Kentucky bluegrass very well which permits successful establishment of sod-seeded atrazine-resistant grasses such as switchgrass. Atrazine and glyphosate were both effective in suppressing sod in our studies. However, since atrazine provided season-long control of annual weeds and white clover the resulting switchgrass stands were more vigorous at the conclusion of the first growing season.

An unexpected advantage of sod seeding was observed during these experiments. Warm-season grass remnants, primarily big bluestem, rapidly increased in vigor in response to the atrazine or glyphosate applications (Fig. 1). Although very few remnant plants were evident in the upland pastures at the beginning of the experiment there were often enough by the end of the season that seeding would not have been necessary. A similar increase in warm-season grasses with atrazine or glyphosate treatment was observed in tallgrass prairie in 1979 and 1980 by Waller and Schmidt (Improvement of Nebraska tallgrass range using atrazine or glyphosate. J. Range Manage. In press.). In the subirrigated pasture resident white clover, which escaped glyphosate injury, was encouraged on glyphosate treated plots.

When renovating unplowed pastures dominated by bluegrass where warm-season prairie once existed, the vegetation should be carefully examined the previous

Fig. 1. Photo taken in late June following a spring seeding showing seeded switchgrass around clumps of resident big bluestem. This plot received paraquat at 0.3 kg/ha plus atrazine at 2.2 kg/ha. The marker is divided in 5-cm increments.

growing season for stunted warm-season grass remnants such as big bluestem. Our studies show that the following spring in the presence of dormant warm-season remnants, paraquat at 0.3 plus atrazine 2.2 kg/ha or glyphosate broadcast 1.1 or 2.2 kg/ha permit successful establishment of seeded switchgrass around the clumps of resident warm-season grasses. An established stand of seeded and resident warm-season grasses ready for grazing will generally occur at the end of the first growing season.

ACKNOWLEDGMENTS

The authors wish to thank the Old West Regional Commission for financial support for this research. Gratitude is extended to Mr. Max Eberspacher, Mr. Roger C. Luebke, and Mr. Ronald R. Schernikau for providing pastures in which to conduct the reseeding trials.

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