Boulder County Parks and Open Space Small Grants
Report for 2004 Research Project

Management Strategies for the Establishment of Warm and Cool Season Grasses in Downy Brome Infested Rangeland

Submitted by

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SECTION 1: Abstract

Management strategies are needed to reclaim the productivity and biological diversity of degraded grasslands. The most important phases of ecological reclamation are the reintroduction and establishment of native or other desirable species. We used the selective herbicide, **Plateau®** (imazapic), as a management strategy to improve perennial grass establishment by controlling downy brome and other annual weeds during desirable species establishment. A replicated field experiment was established to evaluate time of grass seeding, time and rate of herbicide application, and the response of cool and warm season grasses to planting date and herbicide treatments. Information derived from this research project will help to establish guidelines to improve the success of the establishment process. Native grass reintroduction should be enhanced if grass seedlings are provided a weed-free environment during establishment.

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SECTION 2: Introduction

The establishment of perennial grasses in downy brome infested rangeland presents significant challenges. In areas with highly variable precipitation, grass establishment can fail simply due to lack of sufficient moisture for germination and establishment. The combination of limited moisture and competition from annual weeds often means significant reductions in establishment. Downy brome grows as a winter or early spring annual, depleting available soil moisture before native grass species germinate. Selective herbicides could provide the necessary weed-free period for establishment by controlling both winter annual grasses and summer annual broadleaf weeds. The objective of this proposal was to evaluate the use of **Plateau®** herbicide for the control of downy brome to aid perennial grass establishment. Research objectives will determine the appropriate rate and timing for Plateau applications (fall vs spring), time of seeding (fall vs spring) and response of cool and warm season grasses to herbicide applications and planting date.

This research will provide Boulder County Parks and Open Spaces with valuable information on downy brome control and how to increase forage resources. A major cost involved in these ecological reclamation projects is the investment in native cool and warm season grass seed. Depending on the seeding rates and species composition seed cost alone can be $100 to $200 per acre or more. Plateau effectively controls downy brome and should improve native grass establishment. With refinements, seeding rates could be reduced, increasing the number of acres that could be reclaimed annually.

The concept of using vigorous perennial grasses to quickly establish and compete with downy brome seedlings was first proposed by Evans et al. (1970). Since that time research efforts have focused on identifying grass species that would establish rapidly and compete effectively with downy brome (Buman et al., 1988; Rose et al., 2001). Unfortunately, the most successful perennial grasses identified were not native and therefore do not provide suitable materials for ecological restoration projects that wish to focus on the establishment of native species. Restoration research conducted in the Nebraska Sandhills with warm season grasses, identified a family of herbicides called the "imidazolinones" (IMI for short) as very effective tools for warm season grass restoration (Masters and Nissen, 1998; Masters et al, 1996). The culmination of this research was the registration of imazapic or "Plateau" for pasture and range weed management. The Nebraska Sandhills ecosystem is much more favorable for restoration work due to the quantity and distribution of precipitation compared to Colorado; however, we propose to use similar strategies under a less favorable environment.

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SECTION 3: Methods

A field experiment was established as a strip-strip plot design with four replications. Each experimental unit was 80 ft wide by 160 ft long, consisting of four perennial grass treatments seeded either in the fall or spring (total of eight strips per block). The 160 ft strips were subdivided into 10 ft sections and 16 herbicide treatments were applied perpendicular to seeded rows of grass. Eight herbicide treatments were applied in the fall and eight in the spring after downy brome emergence, but before grass seeding. Herbicide treatments were applied using a small plot CO_2 backpack sprayer with a six-nozzle boom covering approximately 10 ft. Application volume was 20 gal/A and spray solution included the appropriate surfactant.

The seven perennial grasses seeded in this study were; blue grama (*Bouteloua gracilis*-BOUGR), sideoats grama (*Bouteloua curtipendula*-BOUCU), big bluestem (*Andropogon gerardii*-ANDGE), Indiangrass (*Sorghastrum nutans*-SORNU), green needle-grass (*Stipa viridula*-STIVI), Western wheatgrass (*Agropyron smithii*-AGRSM), and prairie Junegrass (*Koelaria cristata*-KOECR). Blue grama , side-oats grama, big bluestem, and Indiangrass are native warm season grasses, while the other species are native cool season grasses. Crested wheatgrass (*Agropyron desertorum*-(AGRCR), Luna pubescent wheatgrass (*Agropyron* trichophorum-AGRSP), Western wheatgrass (*Agropyron smithii*-AGRSM), blue grama (*Bouteloua gracilis*- BOUGR), and sideoats grama (*Bouteloua curtipendula*-BOUCU), were remnant grasses that had already been established at this site. The seeding rate was approximately 440 per live seed/m^2 for all treatments and a 10 ft range drill was used for seeding. Cool and warm season grasses were seeded separately and as a mixture, while one strip was left unseeded as a control.

Visual estimates of downy brome control were taken in the spring and fall of 2003 and 2004. Downy brome and perennial grass biomass data were collected in fall of 2003 and 2004. Species composition estimates were taken in the fall of 2004. For logistical reasons grasses were seeded in strips rather than randomized within each sub-plot; therefore, the experiment is more correctly called a strip-strip plot design.

SECTION 4-Results and Discussion.

Downy Brome Control

Plateau applied in fall, even at rates as low as 4 oz/A, provided excellent downy brome control. As the Plateau rate increased downy brome control increased, with the 12 oz/A treatment controlling 100% of downy brome in May 2003 **(Table 1).** In general, downy brome control with fall Plateau applications were significantly better than spring applications and caused less initial injury to grass **(Table 2)**. Fall Plateau applications also provided more consistent control of tansy and blue mustard compared to spring applications in 2003. These annual broadleaf weeds can also compete with established and seeded grass.

Fall Plateau applications also provided good to excellent downy brome control two years after treatment (YAT). The two year downy brome ratings remained fairly consistent from 2003 through 2004. This is an indication of sustained, long term downy brome control with Plateau and the apparent competitiveness of the remnant and seeded grasses that were established.

Spring applied Plateau did not perform as well as fall applications. Other research conducted in Colorado and throughout the Western United States has shown that downy brome is controlled poorly when Plateau is sprayed on downy brome that has started to tiller (this study mirrors these findings). For best results it is critical to apply Plateau on downy brome either pre-emergence or at seedling growth stage prior to tillering.

Plateau's soil residual activity for downy brome control was apparent at the September 2003 evaluation. Downy brome that had tillered when Plateau was applied in the spring was not controlled; however, downy brome that had just emerged in August and September 2003 was controlled with 12 oz/A of Plateau approximately 1½ years after treatment (97% control).

Roundup applied in spring or fall controlled downy brome similarly; however, perennial grasses were injured by the spring treatment as reflected in decreased biomass harvested. Cool season grasses had emerged before the April 2002 application date and were injured by this treatment. Cool season grass injury could be avoided if Roundup was applied in the late fall to early spring when perennial grasses are dormant. Roundup provided excellent downy brome control the year of treatment but no residual control was detected. We also observed that Roundup treatments were a lot "weedier" than Plateau plots. Yellow alyssum (*Alyssum alyssoides*), redstem filaree (*Erodium circutarium*),, blue mustard (*Chorispora tenella*), flixweed (*Descurainia sophia*), kochia (*Kochia scoparia*), and field bindweed (*Convulvus arvensis)* emerged after Roundup treatments were applied. Plateau plots were less weedy than Roundup treated plots due to the broad spectrum of weed species controlled and soil residual activity of Plateau.

Grass Response

Remnants of Luna pubescent wheatgrass, Western wheatgrass, blue grama, sideoats grama were already present at this site. Drilled grass species included the same remnant grasses plus Indiangrass, big bluestem, prairie junegrass, and green needlegrass.

Remnant grass species were injured more by spring herbicide applications than fall applications in 2003. In 2004, all injured grass recovered except from the 12 oz/A rate of Plateau applied in the spring. In general, warm season grasses are more tolerant to Plateau than cool season grasses, such as wheatgrass species. Spring-applied Plateau caused greater stand loss of cool-season grasses than fall-applied Plateau most likely because cool season grasses were actively growing at the time of spring application. A 20% loss of perennial grass stand was common with the spring herbicide applications in 2003.

Downy Brome Biomass

Downy brome control was also evaluated by taking biomass samples in fall 2003 and 2004. The most dramatic decreases in downy brome biomass were associated with fall herbicide applications. The fall 2 oz/A Plateau application decreased downy brome biomass by 96% in 2003 and 78% in 2004 **(Table 3)**. At 8 oz/A and 12 oz/A downy brome biomass was decreased 100% in 2003 and 2004.

The spring applications thinned and stunted downy brome in 2004. Spring treatments decreased downy brome biomass, but the differences compared to non-treated checks ranged from 40 to 85% in 2003 and 12 to 100% in 2004. Plateau at 12 oz/A applied in spring decreased downy brome biomass by 85% in 2003 and 100% in 2004.

Downy brome biomass (in untreated checks) was much lower in 2004 compared to 2003. This was likely due to poor moisture in the fall and winter, and thus poor downy brome seedling recruitment. Also, excellent spring and summer moisture in 2004 was beneficial to perennial grass species to apparently compete well with downy brome even in plots that were not sprayed.

Downy brome biomass in untreated check plots was approximately 500 lb/A in 2003 compared to approximately 120 lb/A in 2004. The highest downy brome biomass in 2004 was found in spring treated plots with 6 oz/A of Plateau or less (62 to 98 lb/A) compared to approximately 120 lb/A in non-treated control plots.

Downy brome biomass was decreased by 98% with Roundup treatments in 2003 regardless of application timing. This indicates there was no late winter or spring flushes of downy brome after the fall application date. In years with flushes of downy brome after fall Roundup treatments, late emerging downy brome would not be controlled with this treatment because Roundup has no soil activity. Both fall and spring applied Roundup treatments decreased downy brome biomass by 80% in 2004.

Remnant Grass Biomass

Seeded grass did not establish well in 2003 due to hot, dry conditions; thus harvest data are for collective remnant grass species. To keep this data consistent, remnant grass was harvested again in 2004 in the non-seeded plots.

Perennial grass biomass increased as downy brome biomass decreased. There was a dramatic increase in perennial grass biomass in 2003 with the release from downy brome competition **(Table 4)**. Non-treated control plots only produced 44 lb/A of perennial grass in 2003 compared to 623 to 861 lb/A in fall treated plots. Spring sprayed plots produced 204 to 357 lb/A of perennial grass biomass in 2003. Fall applied treatments provided a 15-to 21-fold increase in grass production, while spring applied treatments provided a 5-to 8-fold increase in 2003. The greatest remnant grass biomass in fall applied treatments was from 6 oz/A of Plateau in 2003 and 2004. The greatest grass production in spring treated plots was from 8 oz/A of Plateau in 2003 and 6 oz/A in 2004.

Remnant grass biomass increased 72% in untreated control plots in 2004 compared to 2003. The dramatic increase in perennial grass production in 2004 was likely due to the poor downy brome recruitment (less competition) and excellent spring and summer moisture (benefited perennial grass).

Although perennial grass biomass dropped in all fall treated plots in 2004, they were 61 to 71% higher than nontreated control plots and approximately 23 to 47% higher than spring-treated plots with similar Plateau rates. Plateau sprayed in fall at 6 oz/A produced 621 lb/A of perennial grass compared to approximately 200 lb/A in the untreated control plots. Spring treated plots in 2004 showed slight increases in perennial grass biomass compared to 2003 values, but none were significantly higher than untreated control plots.

Grass Species Composition Changes

Each plot in this experiment was subdivided into spring or fall drilling dates that were seeded to warm, cool, warm plus cool mix, or non-drilled subplots. One of the objectives of this study was to see if a particular grass species would benefit from drilling in fall vs spring, and if there were any grass species-herbicide interactions.

Unfortunately many of the perennial grass species that were drilled into the subplots already existed at this site. This made it nearly impossible to determine whether grass was drilled or already existed.

Estimation of percent grass species composition was recorded in each subplot. Big bluestem, prairie junegrass, and green needlegrass were less than 1% of the species composition, so were not included in the data tables.

There are numerous planting date-herbicide combinations that are possible in this study. To simplify things, only a few of the key combinations will be assessed in this report. Cool season grasses made up approximately 92% of the composition while warm season grasses made up approximately 8% of the perennial grass composition in the untreated control plots where no grass was drilled. These values changed to 60 to 80% cool season composition and 20 to 40% warm season composition in subplots that were sprayed in the fall and drilled in the spring with warm or warm/cool season mixes **(Table 5)**.

Subplots that were sprayed in the fall and drilled in the spring seemed to favor warm season grass recruitment (**Table 6**). Warm season grass composition did not increase in subplots that were drilled only with cool season grasses or non-drilled subplots (even in plots with excellent downy brome control). This likely indicates that warm season grass species are not very competitive with cool season grasses and downy brome at this site. Cool season grass species composition only declined in fall treated plots that were drilled with warm or warm/cool mixes (which reflected an increase in warm species in these same plots).

Blue grama was affected by drilling date and herbicide treatment more than any of the other grass species in this experiment **(Table 7)**. Blue grama composition only increased in plots that were drilled with either warm season or warm/cool season mixes. Blue grama composition also increased with the increased rate of Plateau sprayed in the fall. This is evidence that blue grama increased in plots where greater downy brome control occured. Also the higher rates of Plateau initially injured the cool season grass species and may have given the blue grama seedlings a better chance for survival. The remnant blue grama that existed at this site did not increase in subplots that were drilled only with cool season grasses or non-drilled plots even with increased downy brome control.

Although Western wheatgrass species composition values are generally higher in all treated plots than in nontreated control plots, they are not statistically greater **(Table 8)**. This may be due to the variation that existed through the study site of the cool season grass species. It should be noted that species composition does not account for biomass increases that are apparent in the grass biomass table. Although no data was used to segment grass biomass or canopy cover by species, Western wheatgrass biomass and cover was observed to increase as downy brome control increased.

Indiangrass was present in the warm season grass subplots (0 to 9% in **Table 6**). When drilled and sprayed in the spring Indiangrass tended to increase in composition with the increase in Plateau rate; although this was not statistically different. The 12 oz/A spring treatment of Plateau caused one of the lowest Western wheatgrass composition (20%), one of the lowest remnant grass biomass (310 lb/A in 2004), and one of the highest perennial grass injury rates (63% in 2003), although this was often not statistically different. Downy brome control at the 12 oz/A spring rate was 97%. All of these factors indicate Indiangrass establishment is favored by a lack of competition from cool season perennial grasses and downy brome.

Where poor downy brome control existed (untreated control plots and low rates of Plateau), there was virtually no Indiangrass establishment. Indiangrass also did not establish in any of the Roundup treatments. This may due to the flush of other weedy species (kochia, field bindweed, yellow alyssum, and mustards) that were not controlled by Roundup and interfered with Indiangrass establishment.

Herbicide Treatment Differences

Except for the highest rate of Plateau, fall Plateau applications controlled downy brome better and increased perennial grass biomass with less perennial grass injury than those same treatments applied in spring; however, other research conducted by CSU has shown that Plateau must be sprayed pre-emergence or prior to downy brome tillering in the late summer to early fall for optimal control. An identical study to this one was conducted near Berthoud, Colorado with similar application and drill dates. Fall-applied treatments in this study failed because downy brome was tillering when applications were made. Spring downy brome treatments with Plateau failed to adequately control downy brome the year of treatment. If the Plateau rates are high enough, downy brome will be controlled the following year due to residual activity. Spring treatments at the Berthoud site actually ended up controlling downy brome better in subsequent years than the fall applied treatments due to extended residual activity with spring treatments.

Warm season grass species were favored by fall herbicide applications and spring seeding at this site. Cool season grasses responded well to both spring and fall application dates but increased with the increase in downy brome control (notably fall treatment timing).

Initial grass injury was highest (35 to 75%) with spring treated plots. Although there was remnant grass stand loss with spring treatments, remnant grass biomass was significantly higher in treated plots compared to untreated control plots. Remnant grass that existed in these plots was much more robust and vigorous than grass in untreated control plots that were suppressed by the dense downy brome stand. Grass injury in all fall treated plots recovered by the end of the first growing season while spring treated plots took 2 years to recover.

Plateau vs Roundup

Roundup applied in fall provided similar downy brome control, remnant grass biomass, and species composition to Plateau treatments. Roundup applied in spring provided higher initial downy brome control than any of the Plateau treatments; however, it initially had the highest grass stand injury of any treatment. Spring-applied Roundup was sprayed when the cool season grasses had come out of dormancy. Cool season grass injury could be avoided if Roundup is sprayed before this time. It also should be noted that downy brome should be sprayed in fall or during winter with Roundup when perennial grass species are dormant to avoid the same cool-season grass injury.

Plateau has several advantages over Roundup applications. Plateau's residual soil activity provides longer term downy brome control than Roundup. Plateau also offers pre-emergence control of a broad spectrum of other competitive weed species. In this study, Plateau provided control of yellow alyssum, redstem filaree, blue mustard, flixweed, and field bindweed. Roundup treated plots were much weedier than Plateau treated plots. It is advantageous for rapid establishment of seeded grass and enhanced growth of remnant grasses to eliminate these weeds and avoid their competitive effects.

Plateau's broad spectrum weed control can also be considered a disadvantage. Where desirable native forbs are present, caution may be warranted to prevent their decline with Plateau or any herbicide; however, if downy brome is present in high density these forbs may decline or be eliminated by competition. Research is needed to determine whether Roundup or Plateau will injure or kill native forb species.

Downy brome control with Roundup (both application timings) dropped over time. Roundup treatments provided season-long downy brome control when applied after the last flush of downy brome; however, downy brome that germinated after Roundup had been sprayed was not controlled. It may take several years of Roundup treatments to rid the soil of viable downy brome seed.

Drilling Date Differences

Warm season grass species establishment (notably blue grama) was favored by herbicides sprayed in the fall and drilled in spring; although this was not always statistically different. There was also an increase in warm season composition with the increase in downy brome control with this combination. Warm season grass species did not seem very competitive against established cool season grasses or downy brome.

Cool season grass established well whether drilled in spring or fall. Cool season grass species comprised a larger proportion of species composition at this site (than warm season) and were apparently released from competition with increased downy brome control. When mixed with warm season grass and drilled in the spring there was a drop in cool season composition with the increase in warm season composition. In 2003 there was initial stunting and stand loss of remnant grass (mostly cool season species) that may have benefited the establishment of warm season grasses, especially in fall treatments with increased downy brome control. Remnant grass biomass still remained significantly higher than untreated checks in these subplots

Year to Year Differences

Downy brome biomass dropped dramatically in 2004 compared to 2003. This is likely due to unfavorable fall moisture, which led to poor downy brome recruitment. Downy brome in untreated control plots was approximately 500 lb/A in 2003 and decreased to approximately 120 lb/A in 2004.

With the loss of downy brome, there was an increase in remnant grass biomass in untreated control plots in 2004. Remnant grass dry weights increased from approximately 40 lb/A in 2003 to approximately 200 lb/ac in 2004. Remnant grass biomass in fall Plateau treated plots dropped 22 to 30% in 2004 compared to 2003. At the lower Plateau rates this could be attributed to loss of downy brome control. Fall applied Plateau plots continued to have higher remnant grass biomass than similar spring treated plots because grass injury disappeared sooner and there was higher downy brome control in 2004 compared to 2003.

The increase in remnant grass biomass was not as evident in 2004 because of the large increase in biomass that already occurred in 2003 and the higher grass biomass in untreated control plots in 2004. There was 5-to 21-fold increases in grass biomass in 2003 compared to the untreated control plots. In 2004 there were 2-to 3-fold increases in grass biomass in fall treated plots, while only slight increases in grass biomass in spring treated plots compared to untreated control plots.

Plateau treatments applied in fall provided consistent downy brome control in 2003 and 2004; however, downy brome that was sprayed in the spring with 12 oz/A of Plateau showed major year to year differences in control. Downy brome control with spring-applied 12 oz/A of Plateau was 55% in May 2003, but the herbicide residual activity from this spring-applied treatment controlled 97% of emerged downy brome in fall of 2003.

Key Points

- Both Roundup and Plateau provided rapid downy brome control and perennial grass establishment.
- Remnant grass biomass was 44 lbs/A in untreated control plots compared to 623 to 861 lb/A in fall treated plots in 2003. Remnant grass biomass was 204 to 357 lb/A in 2003 when herbicides were applied in spring.
- Downy brome is best controlled by Plateau when applied before tillering.
- Fall Plateau treatments had less perennial grass injury than similar spring treatments.
- Roundup provided excellent short term downy brome control but several applications may be needed for long term control.
- Roundup must be applied when perennial grass species are dormant to avoid injury.
- Warm season grass species responded favorably to fall herbicide applications followed by warm or warm/cool season mixes drilled in the spring.
- Warm season grasses did not compete well with cool season grasses even with the increase in downy brome control.
- Of the warm season grass species, blue grama responded the most positively to downy brome control.
- Cool season grasses responded favorably to spring or fall seeding dates.
- Composition of warm and cool season grass species was affected by drill timing. species mix, as well as application dates and rates.
- Plateau applied in fall at 6 or 8 oz/A provided the best long term downy brome control with least amount of perennial grass injury and highest remnant grass biomass.

Other Considerations

This study showed how extremes in weather can favor specific plant species. The extremely dry summer of 2002 followed by moist fall and winter favored the germination and growth of downy brome. Poor fall and winter moisture in 2003 followed by fairly cool, wet conditions through the 2004 growing season favored perennial grasses at this site.

In areas with a mix of perennial grass and downy brome it may not be necessary to spray downy brome unless the area is being managed for cattle grazing or competition with downy brome is causing undesirable changes in native species composition. The cyclic weather patterns may dictate which species dominates in any given year. Downy brome's existence depends upon precipitation timing, seed production, disturbance, and other factors. In years with optimal fall moisture for downy brome germination and establishment downy brome will prosper, while in years that favor competitive cool and warm season grasses, these grasses may provide competition for soil moisture, nutrients, and sunlight.

In areas that are managed for cattle grazing it would be beneficial to spray downy brome to potentially increase cattle stocking rates or duration of grazing with the increase in perennial grass that is available. Our study illustrates that it is possible to increase perennial grass production 5-to 21-fold by spraying Plateau or Roundup in the fall (pre-emergence or early post). Even in years with ideal weather conditions for optimal perennial grass production it may be possible to increase grass biomass 2-to 3-fold by controlling downy brome.

In areas with dense stands of downy brome and a sparse population of remnant perennial grass species, a more aggressive approach of spraying plus seeding desirable grasses may be necessary to revegetate an area. Lack of competition from downy brome provided an increase in warm and cool season grass species composition, biodiversity, and collective biomass in this experiment.

We would like to thank Boulder Open Space for cooperating with us on this project. They provided us with financial support, site, use of drilling equipment, seed, and labor for much of this project.

Table 1. Downy brome control

Herbicide[a]	Rate	Timing	Downy brome control May 2003	September 2003	March 2004	November 2004
	(oz/A)		------(%)------			
Plateau	2	Fall	73	82	76	66
	4	Fall	83	86	86	80
	6	Fall	91	93	94	93
	8	Fall	91	99	97	89
	12	Fall	100	96	98	98
Roundup[b]	16	Fall	98	95	85	59
Plateau	2	Spring	30	24	28	8
	4	Spring	35	45	59	41
	6	Spring	39	68	73	35
	8	Spring	50	71	78	65
	12	Spring	55	97	97	97
Roundup[b]	16	Spring	95	85	78	61
Control			0	0	0	0
LSD (0.05)			10	11	10	15

[a] Methylated seed oil added to all treatments at 400 oz/A.
[b] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 2. Remnant Grass Injury

Herbicide[a]	Rate	Timing	Grass injury May 2003	July 2003	March 2004	July 2004
	(oz/A)		(%)			
Plateau	2	Fall	21	0	0	0
	4	Fall	29	0	0	0
	6	Fall	31	4	0	0
	8	Fall	45	6	0	0
	12	Fall	51	5	0	0
Roundup[b]	16	Fall	50	0	0	0
Plateau	2	Spring	35	20	0	0
	4	Spring	66	25	0	0
	6	Spring	64	23	0	0
	8	Spring	68	28	21	0
	12	Spring	63	31	28	10
Roundup[b]	16	Spring	75	10	0	0
Control			0	0	0	0
LSD (0.05)			15	10	7	4

[a] Methylated seed oil added to all treatments at 400 oz/A.
[b] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 3. Downy brome biomass

Herbicide[a]	Rate (oz/A)	Timing	Downy brome dry weight 2003	2004
			-------------(lb/A)------------	
Plateau	2	Fall	20	29
	4	Fall	5	7
	6	Fall	2	0
	8	Fall	0	0
	12	Fall	0	0
Roundup[b]	16	Fall	9	16
Plateau	2	Spring	303	98
	4	Spring	326	62
	6	Spring	170	67
	8	Spring	160	27
	12	Spring	94	0
Roundup[b]	16	Spring	14	16
Control			515	119
LSD (0.05)			13	27

[a] Methylated seed oil added to all treatments at 400 oz/A.
[b] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 4. Remnant grass biomass

Herbicide[a]	Rate (oz/A)	Timing	Remnant grass dry weight 2003	2004
			--------------(lb/A)-------------	
Plateau	2	Fall	797	562
	4	Fall	815	608
	6	Fall	861	621
	8	Fall	716	542
	12	Fall	623	487
Roundup[b]	16	Fall	848	455
Plateau	2	Spring	204	330
	4	Spring	226	321
	6	Spring	223	362
	8	Spring	357	419
	12	Spring	259	310
Roundup[b]	16	Spring	348	343
Control			41	223
LSD (0.05)			213	223

[a] Methylated seed oil added to all treatments at 400 oz/A.

[b] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 5. Grass species composition sub-plot drilled in spring with warm or cool season grasses [a]

			Grass species composition			
			Drilled with warm		Drilled with cool	
Herbicide[b]	Rate (oz/A)	Timing	Warm[c]	Cool[c]	Warm	Cool
			(%)			
Plateau	2	Fall	18	83	11	90
	4	Fall	33	68	3	96
	6	Fall	34	66	5	96
	8	Fall	32	71	3	98
	12	Fall	40	59	5	96
Roundup[d]	16	Fall	30	70	9	91
Plateau	2	Spring	28	73	5	95
	4	Spring	7	95	0	100
	6	Spring	35	71	14	69
	8	Spring	10	88	9	95
	12	Spring	25	73	5	83
Roundup[d]	16	Spring	26	73	1	80
Control			22	78	8	84
LSD (0.05)			21	22	15	26

[a] Data collected at final evaluation in fall 2004.
[b] Methylated seed oil added to all treatments at 400 oz/A.
[c] Indicates warm or cool season grass composition when drilled either with warm or cool season grasses.
[d] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 6. Grass species composition sub-plot drilled in spring with warm season grasses.[a]

Herbicide[b]	Rate	Timing	BOUGR	BOUCU	SORNU	AGRSM	AGRSP	AGRCR
			Grass species composition					
	(oz/A)		(%)					
Plateau	2	Fall	11	6	1	55	25	3
	4	Fall	20	13	0	35	31	1
	6	Fall	25	8	1	26	36	4
	8	Fall	26	3	3	38	23	11
	12	Fall	35	0	5	38	20	1
Roundup[c]	16	Fall	15	15	0	36	30	4
Plateau	2	Spring	14	14	0	36	19	18
	4	Spring	4	3	0	65	20	10
	6	Spring	11	23	1	23	36	13
	8	Spring	5	1	4	36	33	19
	12	Spring	8	8	9	20	44	9
Roundup[c]	16	Spring	21	5	0	18	45	10
Control			12	10	0	29	26	23
LSD (0.05)			16	16	6	31	24	18

[a] Data collected at final evaluation in fall 2004.
[b] Methylated seed oil added to all treatments at 400 oz/A.
[c] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 7. Blue grama composition vs drill timing and type.[a]

Herbicide[b]	Rate	Timing	Blue grama composition: Spring-seeded Warm[c]	Mixed	Cool	None	Fall-seeded Warm	Mixed	Cool	None
	(oz/A)		(%)							
Plateau	2	Fall	11	3	1	1	6	4	1	4
	4	Fall	20	8	0	0	3	5	0	0
	6	Fall	25	15	3	4	11	10	6	1
	8	Fall	26	15	0	0	10	16	0	3
	12	Fall	35	24	0	0	3	18	1	3
Roundup[d]	16	Fall	15	6	0	5	16	8	3	1
Plateau	2	Spring	14	19	3	3	10	5	3	3
	4	Spring	4	6	0	0	1	9	4	3
	6	Spring	11	10	0	0	4	6	0	0
	8	Spring	5	5	3	1	9	3	3	0
	12	Spring	8	8	3	1	13	14	5	6
Roundup[d]	16	Spring	21	18	1	1	23	9	0	0
Control			12	11	2	3	8	9	0	2
LSD (0.05)			16	16	4	6	10	13	7	5

[a] Data collected at final evaluation in fall 2004.
[b] Methylated seed oil added to all treatments at 400 oz/A.
[c] Indicates warm, mix, cool, or no grass drilled in spring or fall.
[d] Ammonium sulfate added to all Roundup treatments at 32 oz/A.

Table 8. Western wheatgrass composition vs drill timing and type.[a]

Herbicide[b]	Rate	Timing	Western wheatgrass composition							
			Spring-seeded				Fall-seeded			
			Warm[c]	Mixed	Cool	None	Warm	Mixed	Cool	None
	(oz/A)		(%)							
Plateau	2	Fall	55	61	45	41	36	24	36	46
	4	Fall	35	40	36	31	63	44	56	39
	6	Fall	26	38	34	50	14	24	24	39
	8	Fall	38	59	56	49	41	28	25	51
	12	Fall	38	31	54	75	39	30	49	54
Roundup[d]	16	Fall	36	51	69	41	34	78	63	63
Plateau	2	Spring	36	46	38	41	70	51	36	33
	4	Spring	65	56	59	48	44	36	43	34
	6	Spring	23	38	26	26	45	41	58	51
	8	Spring	36	49	41	60	48	53	38	36
	12	Spring	20	56	26	41	26	26	23	34
Roundup[d]	16	Spring	18	23	36	64	45	55	60	39
Control			37	34	21	35	37	32	25	38
LSD (0.05)			31	36	30	40	36	34	37	38

[a] Data collected at final evaluation in fall 2004.
[b] Methylated seed oil added to all treatments at 400 oz/A.
[c] Indicates warm, mix, cool, or no grass drilled in spring or fall.
[d] Ammonium sulfate added to all Roundup treatments at 32 oz/A.