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The effects of varying seeding rates of Bouteloua curtipendula and mowing on native plant establishment in a new prairie reconstruction

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THE EFFECTS OF VARYING SEEDING RATES OF *BOUTELOUA CURTIPENDULA* AND MOWING ON NATIVE PLANT ESTABLISHMENT IN A NEW PRAIRIE RECONSTRUCTION

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Ryan Leon Welch

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ABSTRACT

A major problem early in prairie reconstruction is weed competition. Research has shown that mowing in the first year can increase establishment and survival of prairie plants. The use of nurse crops (companion crops) has been suggested as an alternative to mowing for weed suppression. The goal of this study was to examine various seeding rates of *B. curtipendula*, as a nurse crop in mowed and unmowed plots to determine if it suppressed weeds and aided in the establishment of natives. We hypothesized that increasing the seeding rate of *B curtipendula* will reduce weed growth and promote an increase in native seedling numbers. In addition we hypothesized that number of the native seedlings in mowed plots with no *B. curtipendula* seed will be similar to unmowed plots seeded with *B. curtipendula*. Seeds of 25 different species of grasses and forbs were broadcast on June 18th at Neal Smith Wildlife Refuge at a seeding rate of 22 seeds/m^2. *B. curtipendula* was also broadcast seeded at rates of 0, 22, 43, 173, and 345 seeds/m^2. The site was mowed mid-August of the first growing season and approximately every three weeks of the second growing season. Sampling was done in early September 2005 and in June and mid August 2006. Native seedling counts, biomass clippings, basal cover, and photosynthetic light were measured. Varying seeding rates of *Bouteloua curtipendula* had no significant effect on native species composition or weed biomass. Mowing had negative effects on native species composition, especially native grasses.

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Entitled: The Effects of Varying Seeding Rates of *Bouteloua curtipendula* and Mowing on Native Plant Establishment in a Prairie Reconstruction

has been approved as meeting the thesis requirements for the

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Date Dr. Sue A. Joseph, Dean, Graduate College

DEDICATION

For Andrea, Otis *Bouteloua*, and the entire Welch Family

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INTRODUCTION

Literature Review

The first prairie reconstruction was started in 1936 at the University of Wisconsin Arboretum. This was the first attempt to recreate an ecosystem that humans had dismantled. Prairie reconstruction spread to other Midwestern states in the 1950's, and 1960's (Smith 1995). Reconstructions were done on public lands, private lands, corporate headquarters, and university campuses for aesthetic and educational uses. Smith initiated a prairie reconstruction on the University of Northern Iowa campus in 1973. Five species of native grasses were initially planted and forb species were added later. The 8 acre site has served as an outdoor laboratory as well as providing opportunities for management and reconstruction research (Smith 1995).

The first large scale prairie reconstruction was started at the Fermi National Accelerator Laboratory in Batavia, Illinois in 1974 by Robert Betz, with the support of the Lab's founding director, Robert Wilson, and the Illinois Chapter of The Nature Conservancy. More than 70 different native species were planted on approximately 1000 acres (Mlot, 1990).

Since then a number of large scale restoration and reconstruction projects have been initiated throughout the Midwest. In 1991, the Walnut Creek National Wildlife Refuge and Prairie Learning Center was established near Prairie City, Iowa in Jasper County. This area was later renamed the Neal Smith National Wildlife Refuge. When completed this site could consist of 8654 acres of reconstructed prairie and savanna ecosystems (Smith 1995).

The Midewin National Tallgrass Prairie, a 15,454 acre area located 40 miles southwest of Chicago, was established in 1996 on the former U.S. Army Joliet Ammunition Plant. This project is directed by the U.S. Forestry Service in cooperation with the Illinois Department of Natural Resources. It has been designated by the U.S. Forestry Service as the first national tallgrass prairie (U.S. Department of Forestry, 2002).

Prairie reconstruction projects differ in size, composition, and purpose. Consequently each prairie reconstruction offers unique challenges. Many of the ecological changes of succession that take place during a reconstruction are little or poorly understood, especially those involving the conversion of agricultural land to prairie (Mlot 1990, Camill et al. 2004). Established mixtures of native species in mature reconstructions out-compete non native or invasive annuals or perennials that are commonly referred to as weeds. However, weeds often inhibit the establishment of the native species during the reconstruction process (Blumenthal et al. 2003). Any reduction of weeds prior to planting will reduce competition facing prairie species. Therefore, it is important in prairie reconstruction to reduce early weed competition to achieve a high percentage of establishment of native seedling.

The amount of weed seed present in the seed bank of a planting site is perhaps the most variable and unpredictable factor in prairie restoration (Schramm 1976). Seed rain as well as herbaceous residue that persists through the winter can contribute to a seed bank for weedy vegetation (Betz 1984). The species composition and density of weed seed in soil vary greatly and in many cases are linked to the cropping history of the land (Buhler et al. 1997). In most agronomic situations, weed seeds usually germinate in the first year after production. Some of the more common weed species such as giant foxtail (*Setaria faberii* Herrm), velvetleaf (*Abutilon theophrasti* Medic.), common ragweed (*Ambrosia artemisifolia* L.), *Amaranth* species, and common lambsquarters (*Chenopodium album* L.) have average emergence rates of 3 to 31% the first year (Buhler et al.1997). Buhler and Harzler (2001) found that seedlings of velvetleaf, common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), wooly cupgrass (*Eriochloa villosa* (Thunb.) Kunth), and giant foxtail emerge at a rate of 1-9% from the seed bank in the second and third years. Velvet leaf and common waterhemp seed persisted into the fourth year with emergence percentages of 5-12% of what was originally in the seed bed. Davis and Fay (1989) observed that knapweed (*Centaurea nigra* L.) seed retains over 50% viability after burial for up to five years.

Some suggest that dealing with weed control should begin with the design of the seeding mixture and planting rates. Robert Betz (1984) conceived the idea of using selected prairie species to compete with weedy species. He proposed using a "prairie matrix" of aggressive warm season grasses and forbs to out-compete the weedy species present in reconstruction establishments (Smith 1995). Betz (1984) theorized that the aggressive prairie species would out-compete weeds in prairie reconstructions. He opined that species which persist during degradation or destruction of prairie were the most aggressive. Therefore, he proposed that these species should be planted initially in a reconstruction to out compete weeds. He tested this concept in prairie reconstruction at the Fermi National Accelerator Laboratory. Twenty-three "aggressive" species including big bluestem (*Andropogon gerardii* Vitman) and Indian grass (*Sorghastrum nutans* (L.) Nash), were initially seeded to out compete the onslaught of annual and biennial weeds during the first few years of a reconstruction. Once these "aggressive" species became sufficiently established to provide enough fuel for a good burn, he followed with a second seeding of more "conservative" species such as purple prairie clover (*Dalea purpurea* (Vent.) Rydb.) and prairie dropseed (*Sporablis heterolepis* (Gray) Gray). Betz's seeding mixture was bulk harvested from other local sites so no information is available regarding seeding rate of individual species (Mlot 1990).

The information on the seeding rate of the aggressive species Betz planted would have been useful as appropriate seeding rate of species can be crucial. If the "aggressive" species are not seeded at a high enough rates then weed suppression does not occur. On the other hand, if their seeding rates are too high, there is a risk of having a few species dominate the prairie reconstruction.

Much of the research on the subject of seeding rates deals with native grass establishment in range management settings, with little or no mention of native plant establishment in a restoration context. Launchbaugh and Owensby (1970) recommend that planting of excessive amounts of seed be avoided due to competition for environmental resources. Their research results indicate that only a portion of the viable grass seeds planted will produce seedlings due to limited resources such as moisture, light, and soil nutrients. However, light and water resources may not be as limiting further east in the tallgrass prairie region.

Diboll (1997) presents a contrary opinion. He indicates that several aggressive species within a mix can dominate a planting and reduce species diversity. He observed that *Solidago* and *Helianthus* species along with early successional species such as *Monarda fistulosa* and *Rudbeckia hirta* and rapidly growing tall grasses like *Panicum virgatum, Elymus canadensis,* and *Andropogon gerardii* can cause stunting of prairie plants and/or reduce the emergence of slower germinating species. This would reduce species diversity rather than contribute to it (Diboll 1997).

Fischback et al. (2006), found that increasing seeding rates of legumes resulted in lower percentages of legume seedlings. They showed that a seeding rate of 14 PLS/m^2 resulted in the highest percentage of seedling establishment where as a seeding rate of 538 PLS/m^2 resulted in the lowest percentage of seedling establishment. Launchbaugh and Owensby (1970) observed that although higher seeding rates in native plants resulted in an increase in total plant numbers, overall plant populations, diversity and stand quality were low especially when compared to the actual number of seeds planted.

Very little work has been done on the effect of varying seeding rates of prairie species to suppress weed growth in a reconstruction. Also, there is little consensus on standard seeding rates for a given species or mixture of species. Often seeding rates depend on a wide variety of factors, such as restoration goals, budget, and site conditions (Launchbaugh and Owensby 1970, Diboll 1997).

Combating undesirable weeds is the first priority when beginning a prairie reconstruction. Cover crops or nurse crops have been used to provide early weed control for a prairie planting (Wilsey 2005). Cover crops are sown before the native prairie seed is planted. Typically they are seeded the summer or fall before a spring seeding of native species. Nurse crops are sown at the same time as the native seed in the reconstruction. Species that germinate quickly and grow rapidly to out-compete the weeds are used. Depending on the cover crop, it may be then harvested or hayed prior to the seeding of natives. If it is a sterile plant, it will be left to continue to compete with weeds and provide soil stabilization. The ability to resist weed invasion while still allowing prairie species to thrive, is the main criteria that should be used when selecting a species for a cover or a nurse crop (Wilsey 2005). Both types increase the ability of slower growing natives to become established. Short lived nurse crops tend to work well for native reconstructions especially in roadside plantings (Tyser et. al., 1998).

Inappropriate nurse crops can cause problems. One problem is that a nurse crop may work too well and not only suppress weeds, but also suppress the native species. Annual rye is often used as a nurse crop in roadside plantings because it germinates well, grows rapidly, and is effective in erosion control. However, it has been demonstrated that a seeding rate of 45/lbs per acre of annual rye significantly reduced native plant establishment (Urice 2002). Another major problem is that most nurse crops are agricultural crops and may persist in the reconstruction. An obvious solution to this problem is to use a native species as a nurse crop.

Alpine studies (Densmore et al. 1990 and Tyser et al. 1998) showed that the use of native grasses as nurse crops increased establishment success of other natives, and was especially beneficial in erosion control on roadsides with slopes. The native cool season grass, Canada wild rye (*Elymus canadensis),* is often used as a nurse crop or cover crop (Christiansen 1990). A study by Wilsey (2005) showed that Canada wild rye plantings had the lowest weed biomass of five cover crops. Other natives were examined for use as nurse crops by Wilsey (2005). These included partridge pea (*Chamaechrista fasciculata)*, Illinois bundleflower (*Desmanthus illinoensis)*, black-eyed susan (*Rudebeckia hirta)*, and side-oats grama (*Bouteloua curtipendula)* (Wilsey 2005). All of these species seemed to be good candidates for nurse crop as they are short lived, have high germination rates, are fast growing, and typically grow well in disturbed areas (Wilsey 2005, Christiansen and Müller 1999). However, they were not effective in controlling weeds. Smooth brome and crown vetch were particular problems during the second growing season (Wilsey 2005).

An alternative approach to enhancing seedling establishment is to control weeds after seeding. Mowing during the first growing season has been effective (Kurtz 1984). This removes the invasive species and allows shorter or later maturing natives to persist due to less competition (Wilson and Clark 2001, Wilson and Partel 2003). Altering mowing time and/or mowing height can be used to target specific invasive weedy species. Mowing throughout the spring has been effective in removal of oatgrass (*Arrhenatherum elatius)* and wild parsnip (*Pastinaca sativa* L) (Wilson and Clark 2001, Kennay and Fell 1990). Kurtz (1994) improved establishment of a wide diversity of plants by mowing in the first growing season at about 3 inch heights, and then, if needed, mowing in the second growing season at about 6 inch heights. By the third growing season, 35 species of forbs and grasses were established and the site was nearly weed free.

Wilson and Partel (2003) showed that mowing promoted native species and suppressed non-natives such as crested wheatgrass (*Agropyron cristatum* (L.) Gaertner). However, they were quick to note that a combination of herbicide, mowing, and native seed introduction seemed to have a better overall effect than mowing alone. This observation was supported by a Nebraska study by Cox and McCarty (1958). They found that mowing and herbicide applications were the best way to suppress Kentucky bluegrass (*Poa pratensis* L.) and increase the cover of native C_4 grasses. Related research by Mintenko et al. (2002) demonstrated that native grasses such as blue grama (*Bouteloua gracilis)* and buffalo grass (*Bouteloua dactyloides)* responded well to mowing and may work as turfgrass. Frequent mowing at varying heights of these grasses maintained approximately 70% ground cover that remained green throughout the summer.

Mowing impeded water infiltration more than burning, but it didn't seem to increase bulk density or soil compaction, as had been previously thought (Shacht et al. 1995). Mowing was once thought to diminish diversity within the prairie especially among perennial forbs. However, Williams (2007) showed that well timed mowing at proper heights can actually be used as a management tool to increase forb diversity. He successfully introduced forbs into a native grass planting that had been established for more than twenty five years.

The use of nurse or cover crops, and mowing after seeding are both used as current management techniques for weed suppression. However, little has been done to evaluate their effectiveness as management tools for weed suppression. Several unanswered questions remain. What native species are most effective as nurse crops in weed suppression and native establishment? What is the best seeding rate for nurse crops to effectively suppress weeds while allowing a diverse establishment of native plant species? Can nurse crops be as effective as mowing for weed suppression in the early stages of a prairie reconstruction?

Research Hypothesis and Objectives

This study tests the hypothesis that side-oats grama (*Bouteloua curtipendula)* (Mich.) Torrey, can be used as a nurse crop to suppress weeds and increase native species establishment similar to mowing in new prairie reconstructions.

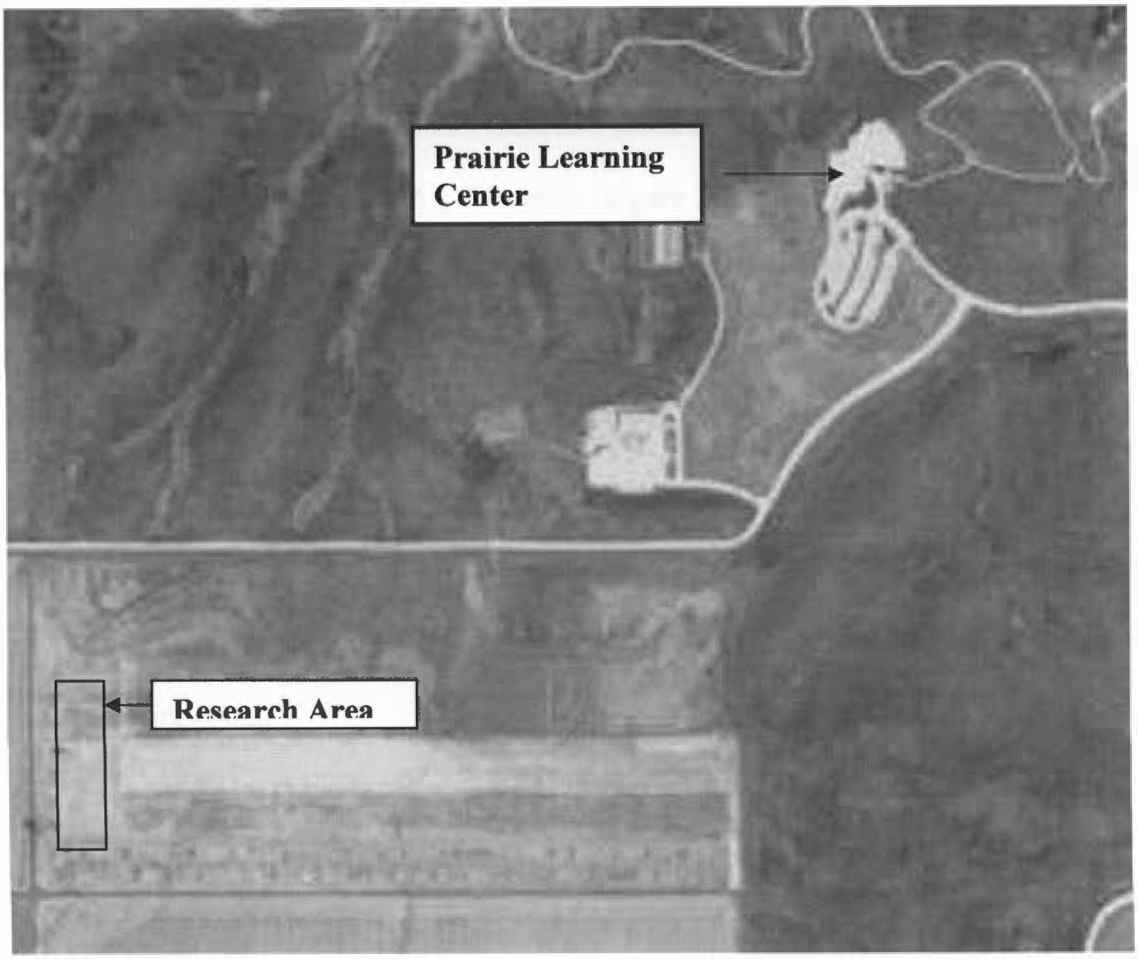
The objectives of this study were to assess and compare the effects of different seeding rates of *Bouteloua curtipendula* and mowing on weed emergence and native seedling establishment to determine the effectiveness of *B. curtipendula* as a nurse crop for weed suppression and native species establishment.

CHAPTER 2

MATERIALS AND METHODS

Site Description

The study site (41° 33' N, 93° 17' W) is located on the Neal Smith National Wildlife Refuge 7 miles south of Prairie City, in Jasper County Iowa. It is approximately 1/4 of a mile SW of the Prairie Learning Center (Figure 1) on upland soils. The soil in the northern 3/4 of the site is classified as Mahaska silty clay loam, and the southern 1/4 of the site is classified as a Taintor silty clay loam (NRCS websoilsurvey). The rainfall for this area was 31.75 inches for 2005 and 33.69 for 2006 (Hillaker). The area was cropped with soybeans in 2004 and corn in 2003.



http://cairo.gis.iastate.edu/server.cgi/22605.jpg?layer=naip_2006&zoom=5&x0=475434&y0=4600570&pwidth=600&pheight=600&format=jpg

Figure 1: Aerial view of a portion of Neal Smith Wildlife area, showing the Prairie Learning Center, and location of the research area.

Experimental Design

The experiment used a randomized two block design. Each block was 60m x 100m and consisted of twenty 15 x 20m plots (Figure 2). Block 1 consisted entirely of Mahaska silty clay loam, while Block 2 was divided between Mahaska silty clay loam (1/2 of the northern portion), and Taintor silty clay loam (1/2 of the southern portion). A 5m wide unseeded mowed strip separated the two blocks. The total area for each block was 6000m^2, with a total research area of approximately 12,600m^2. Each plot was randomly assigned one of 10 different treatments. There were 5 different seeding rates of side-oats grama, 0, 22, 43, 173, and 345 seeds/m^2. Each of these had a mowing or a non-mowing component.

The plots were measured and markers were placed at the corners of each plot to identify plot boundaries. These markers also served as points of reference for locating sampling areas. There were 2 replicates of each treatment in each block for a total of 4 replications of each treatment in the study area (Table 1).

Block 1 Block 2

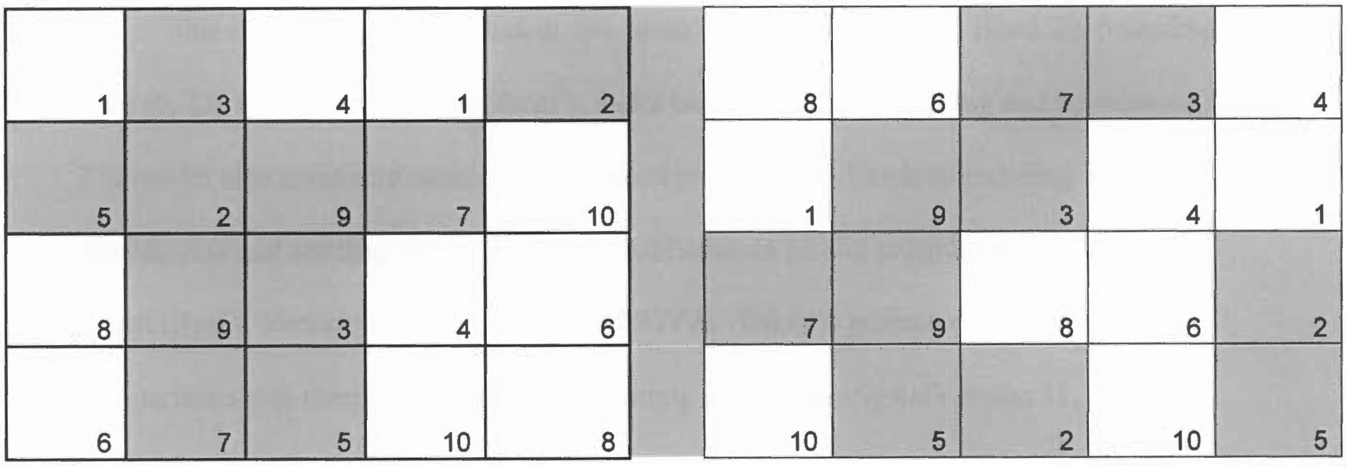


Figure 2: Two block experimental design showing treatment numbers. The shaded areas indicate mowed plots.

Table 1: Treatments and replications used in the experimental design.

Treatments	Total Replications	Replications per Block
Column1		
1=Control no mow: side oats= 0	4	2
2= Control Mow: side oats = 0	4	2
3= Treatment 2 mow: side oats= 2	4	2
4= Treatment 2 no mow: side oats= 2	4	2
5= Treatment 3 mow: side oats= 4	4	2
6= Treatment 3 no mow: side oats= 4	4	2
7= Treatment 4 mow: side oats= 16	4	2
8= Treatment 4 no mow: side oats= 16	4	2
9= Treatment 5 mow: side oats = 32	4	2
10= Treatment 5 no mow: side oats= 32	4	2

General Statistical Approach

The statistical model included: two block factors (Block 1 and Block 2), 5 seeding rates (0, 22, 43, 173, and 345 seeds/m^2), and 2 mowing factors (mowing and no-mowing). The model also takes into consideration interactions such as block by mowing, block by seeding rate and seeding rate by mowing. An Estimate Model program was used in Systat (Systat Version 11, 2004), for the ANOVA. Tukey's protected test for pairwise comparisons was used to compare means among treatments (SystatVersion 11, 2004). All p values were considered statistically different below 0.05.

The data were analyzed using an analysis of variance (ANOVA) with three factors: block, seeding rate, and mowing. All possible 2 and 3 way interactions were analyzed. Repeated measures analysis was done between sampling dates, to determine any statistical differences over time.

Skewness (g1) and kurtosis (g2) were calculated for all data sets. To normalize the data distribution, all count data sets and biomass data sets were square root transformed. Means were back transformed to report the data.

Seed Source and Seed Mixtures

Seed for the project was Source Identified seed from within the 38 county source region specified by Neal Smith National Wildlife Refuge, and purchased from Allendan Seed, 1966 175th Lane, Winterset, IA 50273. Prior to sowing, the seed was stored dry in a temperature and humidity controlled room at the Tallgrass Prairie Center. To ensure accuracy in determining seeding rates for each plot, ten seeds of each species were randomly chosen, weighed, and compared with the seed weight on the tag.

The number of viable seeds sown per unit area (Table 2) was calculated from pure live seed (PLS) information for each of the prairie grasses and forbs. The plots were seeded at a rate of 550seeds/m^2 for all grass and forb species except side-oats grama. The predetermined amounts of seed of all species for each plot, except side-oats grama, were placed into 40 separate bags (one bag for each plot). In addition, predetermined amounts of side-oats grama seed, derived from seeding rate and pure live seed information, were placed into separate bags (one bag for each plot).

Table 2: Seeding information for the native species in the seed mixture. Adjusted seed weights were calculated from a subsample of 175 seeds from each species and based on the % pure live seed.

Grasses		seeds/oz	Total lbs	PLS %	Bulk Weight lbs.	Adj wgt per plot (oz)	Seeding Rate/m²
Big Bluestem	*Andropogon gerardii*	10000	2	74.27	2.7	1	22
Little Bluestem	*Schizachyrium scoparius*	15300	1.3	75.88	1.7	0.62	22
Side-oats Grama	*Bouteloua curtipendula*	8650	5.5	76.27	7.2	Varied	Varied
Canada Wildrye	*Elymus canadensis*	6200	3.21	88.07	3.6	1.27	22
Switchgrass	*Panicum virgatum*	16000	1.22	96.97	1.3	0.46	22
Indian Grass	*Sorghastrum nutans*	11500	1.7	98.52	1.8	0.7	22
Forbs		seeds/oz					
Thimbleweed	*Anemone cylindrica*	16485	1.21	89.55	1.3	0.24	22
Butterfly Milkweed	*Asclepias tuberosa*	3350	5.85	93.07	6.3	1.25	22
New England Aster	*Aster novae-angliae*	67500	0.3	74.29	0.4	0.08	22
White Wild Indigo	*Baptisia leucantha*	1700	11.5	93.98	12.2	3.79	22
Prairie Coreopsis	*Coreopsis palmata*	11000	1.8	70	2.6	0.20	22
Purple Prairie Clover	*Dalea purpurea*	18950	1	94.71	1.1	0.31	22
Showy Tick Trefoil	*Desmodium canadense*	5500	3.56	92.73	3.8	1.42	22
Pale Purple Coneflower	*Echinacea pallida*	5300	3.7	93.73	3.9	1.32	22
Rattlesnake Master	*Erynigium yuccifolium*	7500	2.6	85.47	3	1.16	22
Ox-eye Sunflower	*Heliopsis helianthoides*	6300	3.125	87.95	3.6	0.99	22
Round-Headed Bush Clover	*Lespedeza capitata*	9000	2.175	92.93	2.3	0.84	22
Rough Blazingstar	*Liatris aspera*	15500	1.26	95.02	1.3	0.55	22
Wild Bergamot	*Monarda fistulosa*	75000	0.26	92.16	0.3	0.11	22
Yellow Coneflower	*Ratibida pinnata*	30000	0.65	93.95	0.7	0.20	22
Black-eyed Susan	*Rudbeckia hirta*	92000	0.21	92.9	0.2	0.06	22
Compass Plant	*Silphium laciniatum*	660	29.7	94.54	31.4	7.17	22
Stiff Goldenrod	*Solidago rigida*	41000	0.478	95.24	0.5	0.19	22
Ohio Spiderwort	*Tradescantia ohiensis*	8000	2.45	51.31	4.8	1.05	22
Golden Alexanders	*Zizia aurea*	11000	1.8	91.81	2	0.81	22
Mountain Mint	*Pycanthemum virginianum*	220000	0.18	92.13	0.2	0.08	22

Site Preparation and Seeding

Both blocks were treated with Round-up® herbicide on June 17, 2005. A landscape rake was used to remove litter and crop residue from the site prior to seeding. The plots were seeded June 18, 2005. To ensure evenness of seeding, the bags of seed for each plot were combined with the appropriate side-oats grama for that plot and mixed thoroughly in a bucket. Seed was broadcast by hand. A Brillion (200 Park Ave, Brillion, WI 54110) seed drill was used to roll all of the plots after seeding to ensure good seed to soil contact.

Mowing

A Kubota B2400 (Capital City Equipment Company, 5515 N.W. 2nd Ave, Des Moines, IA 50313) riding tractor/lawn mower was used to mow plots in 2005 and 2006. The plots were mowed once the first year (2005) on August 21. The second year (2006) the plots were mowed four times at approximately 2-3 week intervals, starting May 6, and ending July 20th. All plots were mowed at a height of 8-9 inches each time. No distinct pattern or direction was used during the mowing process.

Sampling Design

One fifteen meter transect was located within each plot using a random number table. Transects were not placed closer than 1 meter from the edge of the plots. Vegetation was sampled in quadrats of $0.1m^2$ at 1 meter intervals along transects. Above ground biomass was sampled in five randomly selected quadrats along the fifteen meter transects. Five below ground biomass cores were randomly sampled in each plot containing side-oats grama. Environmental light was sampled at one random location in each plot.

Field Sampling

Vegetation in the plots was sampled three times; at the end of the first growing season on September 03, 2005, and during the second growing season on June 17, 2006, and August 15, 2006. The following data was collected: number of native plants by species, the presence and frequency of weedy species, species richness, basal coverage, environmental light, above ground biomass of natives and weedy species, and below ground root biomass of side-oats grama. Above ground biomass and environmental light data was collected September 03, 2005, and August 15, 2006. Below ground biomass was sampled August 15, 2006. Biomass samples were collected toward the end of each growing season in order to capture the effect of an entire growing season.

Variables Sampled

Species Richness

The total number of each species of native plants per quadrat were counted and recorded. The species richness was calculated as the total number of different native or weed species per treatment. A 3 way ANOVA by block, mowing treatment, and seeding rate was performed, as well as one way ANOVAs on all statistically significant data. A Shannon's Index of Dominance was calculated for all plots. Three-way ANOVAs by block, mowing treatment, and seeding rate were performed, and one way ANOVAs on all statistically significant data.

Plants per Area

The total number of native plants from all sample quadrats within each plot was divided by 1.5 to determine the number of plants per m^2 for that plot. The plot totals were averaged and the means were analyzed for each of the samples. Species richness, Shannon's Index of Dominance, and total native plant means were analyzed using three way ANOVAs and repeated measures to determine any statistical differences between variables of block, seeding rate, and mowing, as well as statistical differences between sampling periods. Weeds were identified to genus and recorded as being absent or present in each quadrat.

Plant Basal Cover

Basal coverage was sampled for weeds, side-oats grama, native grasses, and native forbs. This data was collected from the $0.1m^2$ quadrats, at one meter intervals along 15 meter transects in each of the plots. The basal coverage was assessed at a height of 2.54 cm or approximately 1 inch from the ground. Basal coverage totals were averaged by plot and statistically analyzed using a three way ANOVA and Tukey's test of means.

Weed Presence

Weeds observed in each quadrat were identified and recorded as present in that area. They were then totaled for each plot and for the entire research area and then divided by the total quadrats sampled to give us a total percent of weed presence throughout the area sampled. A 3 way ANOVA by block, mowing treatment, and seeding rate was run, and one way ANOVAs were run on all statistically significant data of weed species that occupied 4% or greater of the total research area.

Above Ground Plant Biomass

All vegetation within the quadrat was clipped approximately 1 inch above ground level. The clippings were separated into four categories: native grasses, native forbs, side-oats grama, and weeds. The clippings were bagged and dried in drying ovens at a constant temperature of 60° Celsius for three days. The dried vegetation was weighed and recorded. Means for above ground biomass were statistically analyzed using a 3 way ANOVA and Tukey's test of means.

Below Ground Plant Biomass

Core samples of below ground biomass of side-oats grama were collected on August 15, 2006 in all plots except the control plots. Cores samples were 2 ½ inches in diameter and 4 inches deep. Randomly selected side-oats grama plants were sampled and bagged on site. The above ground portion of the plant was clipped an inch above ground level. The cores were washed, the below ground roots were separated and all dirt was removed. Like the above ground vegetation, the below ground roots from these cores were placed in a 60° Celsius drying oven for three days. The samples were then removed, weighed, and recorded. Means for below ground biomass were analyzed using a 3 way ANOVA and a Tukey's test of means.

Environmental Light Data

Li-Cor (4647 Superior St., Lincoln, NE 68504-0425) quantum light sensors were used to measure photosynthetic photon flux density (PPFD) at ground level in all plots. PPFD is the preferred form of measurement to determine the photosynthetically active radiation found in natural sunlight (Li-Cor 2008). Measurements were taken from 11:30 a.m. to 1:30 p.m. on September 03 2005, and August 15 2006. A total of five measurements were taken for each plot at a single randomly selected location. PPFD was expressed as $umols^{-1}m^{-2}$. The data was statistically analyzed comparing mowed and unmowed treatments, as well as seeding rates. These measurements were also correlated with the amount of biomass and number of native species to gain a better understanding of the role light was playing with in the research area. Readings from these measurements were averaged and the total average for each plot was statistically analyzed using a 3 way ANOVA and Tukey's test of means.

CHAPTER 3

RESULTS

Environmental Light Measurements

Light samples were taken with a Li-Cor light meter between 11:30 am and 1:30 pm at ground level in each plot on September 03, 2005 and August 15, 2006. Five readings were taken from the same location within each plot and the readings were averaged. The averages were analyzed using a three-way ANOVA (Appendix 7). Significant differences ($p=0.001$) for surface light were observed between the research blocks. There was a mean of 384.09 (±116.248)μmol s^{-1} m^{-2} for surface light in Block 1, and a mean of 872.198 (±143.427)μmol s^{-1} m^{-2} for surface light in Block 2 (Figure 3).

No significant differences ($p=0.182$) in 2005 and ($p=0.498$) in 2006 were seen for surface light among seeding rates. In 2005, mowing had a significant effect ($p<0.001$) on the amount of surface light that was measured (Appendix 7). No mow treatments had a mean of 228.881 (±91.631)μmol s^{-1} m^{-2} whereas mowed treatments had a mean of 1027.407 (±123.2)μmol s^{-1} m^{-2} (Table 3).

In August of 2006, no significant differences ($p=0.175$) for surface light measurements were seen among research blocks. There were significant differences ($p=0.009$) for surface light measurements among mowing treatments (Appendix 7). No mow treatments had a mean of 292.563 (±104.09)μmol s^{-1} m^{-2} of surface light and mowed treatments had a mean of 618.553 (±104.331)μmol s^{-1} m^{-2} of surface light (Table 3).

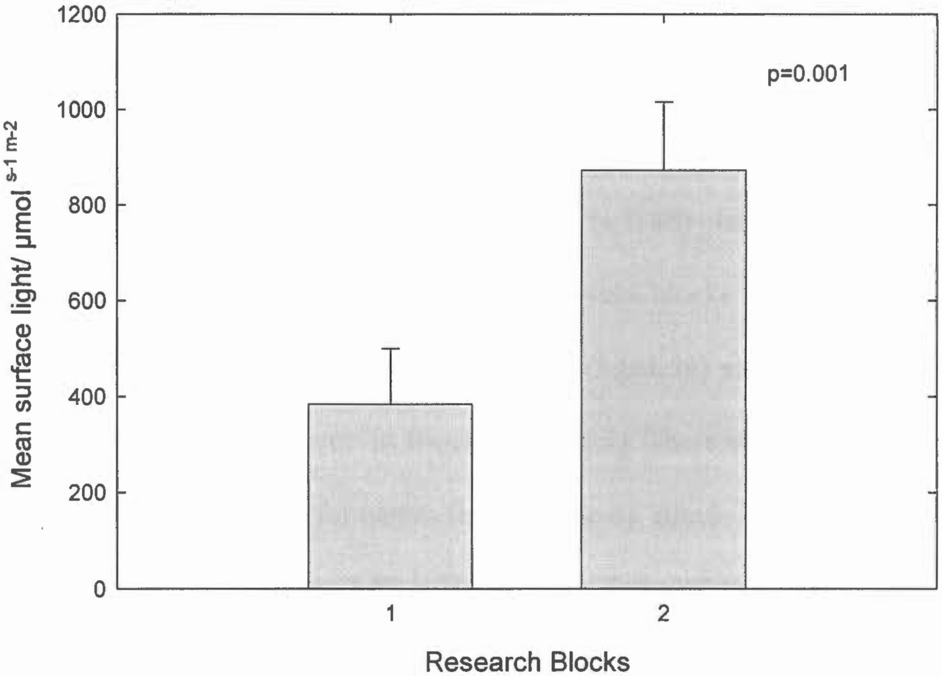


Figure 3: Mean surface light per research plot in September of 2005.

Table 3: Mean surface light and standard errors for mow and no mow treatments in September 2005 and in August 2006.

Year	Mow	No mow	p-value
2005	1027.407 (±123.20)	228.881 (±91.63)	<0.001 *
2006	618.553 (±104.33)	292.563 (±104.09)	0.009 *

* significant difference

Native Plant Establishment (except *B.curtipendula)*

Native plants (except *B.curtipendul*a) were sampled in September of 2005. A 3-way ANOVA was used for data analysis. There was a significant difference between blocks ($p<0.001$) for the total number of native plants (Appendix 7). Block 1 averaged 22.1(±2.64) natives plants/m^2 compared to 4.15 (± 0.88) plants/m^2 in Block 2 (Table 4). There was significant difference ($p<0.001$), between blocks for native grasses except for *B. curtipendula* (Table 4). Block 1 averaged 6.05 (±1.58) native grasses/m^2 compared to 0.50 (±0.28) native grasses/m^2 in Block 2 (Table 4). There was a significant difference ($p<0.001$) between blocks for native forbs (Table 4). Block 1 averaged 16.05(±1.90) native forbs/m^2 compared to 3.65 (± 0.73) native forbs/m^2 in block 2 (Table 4).

Varying the seeding rates of *B. curtipendula* had no significant ($p = 0.636$) effect on total emergence in 2005 (Appendix 7). Likewise mowing in 2005 had no significant effect ($p =0.065$) on the total number of native plants (Table 5).

Native plants (except *B.curtipendula)* were sampled in August of 2006. A 3-way ANOVA was used for data analysis (Appendix 7). There was a significant difference ($p = 0.002$) between blocks for the total number of native plants (Table 4). Block 1 averaged 37.80 (± 2.83) native plants as compared to a mean of 25.40 (± 3.84) in Block 2. There were no significant differences between blocks for the native grass plants (Table 4). Native forb establishment was significantly different ($p<0.001$) between blocks (Appendix 7). Block 1 averaged 28.85 (± 1.69) native forbs compared to 16.90 (± 1.87) native forbs (Table 4). Varying seeding rates of *B. curtipendula* had no significant ($p = 0.601$) effect on total native, native grass, or native forb establishment (Appendix 7).

Total establishment of native grasses and forbs was significantly different (p = 0.002) between mowing treatments (Table 5). Plots not mowed averaged 38.95 (± 3.937) plants, as compared to 24.25 (± 2.336) in mowed plots. Native grass establishment was significantly greater (p<0.001) for no mow plots 14.60 (± 3.04) than mowed plots 2.850 (± 0.499) (Table 5). Native forb establishment did not significantly differ (p = 0.172) between mowing treatments (Table 5).

Table 4: Mean seedling numbers and standard errors for research blocks in September of 2005 and in August 2006.

Year-Plant Group	Block 1	Block 2	p-value
2005			
Total Natives	22.10 (±2.64)	4.15 (±0.88)	<0.001 *
Grasses	6.05 (±1.58)	0.50 (±0.28)	<0.001 *
Forbs	16.05 (±1.90)	3.65 (±0.73)	<0.001 *
2006			
Total Native	37.80 (±2.83)	25.40 (±3.84)	0.002 *
Grasses	8.95 (±1.86)	8.50 (±3.11)	0.362
Forbs	28.85 (±1.69)	16.90 (±1.87)	<0.001 *

* significant difference

Table 5: Mean plant numbers and standard errors for mow and no mow treatments in September of 2005 and in August 2006.

Year- Plant Group	Mow	No-Mow	p-value
2005			
Total Natives	10.90 (±2.41)	15.35 (±3.15)	0.065
Grasses	1.80 (±0.63)	4.75 (±1.66)	0.077
Forbs	9.10 (±2.1)	10.60 (±1.95)	0.217
2006			
Total Natives	24.25 (±2.34)	38.95 (±3.94)	0.002 *
Grasses	2.85 (±0.5)	14.60 (±3.04)	<0.001 *
Forbs	21.40 (±2.20)	24.35 (±2.24)	0.172

* significant difference

B.curtipendula Establishment

B. curtipendula plant establishment was sampled in September of 2005. A 3-way ANOVA was used for data analysis (Appendix 7). Significant differences ($p<0.001$) were found between blocks for the total number of *B. curtipendula* plants. There was a mean of 14.45 (±3.29) plants sampled in Block 1, while Block 2 had a mean of 4.90 (±1.49) (Table 7). Mowing treatments had no significant effect ($p=0.201$) on the establishment of *B. curtipendula* (Appendix 7).

Varying seeding rates of *B. curtipendula* did have a significant effect ($p<0.001$) on its ability to become established (Table 7). Although there were no significant differences among the 0, 22, and 43 seeds/m^2 seeding rates, or between the 22, 43, and 173 seeds/m^2 seeding rates (Table 6), there were significant differences between the rate of 345 seeds/m^2 and all other seeding rates except 173 seeds/m^2 (Table 6).

Table 6: Tukey's means test of comparison between varying seeding rates of *B.curtipendula* in September 2005.

Matrix of pairwise comparison probabilities:

	0	22	43	173	345
0	1.000				
22	0.230	1.000			
43	0.200	1.000	1.000		
173	0.000*	0.120	0.140	1.000	
345	0.000*	0.029*	0.036*	0.971	1.000

* significant differences

Table 7: Mean plant numbers and standard errors for *B.curtipendula* per research block in September of 2005 and August of 2006. Reported means were back transformed from square root transformed data.

Year	Block 1	Block 2	p-value
Mean *B.curtipendula*/m^2 2005	14.45 (±3.29)	4.90 (±1.49)	<0.001 *
Mean *B.curtipendula*/m^2 2006	15.40 (±3.93)	4.65 (±1.30)	<0.001 *

*significant difference

Table 8: Mean plant numbers and standard errors for *B. curtipendula* plants per seeding rate of *B. curtipendula* in September of 2005 and August of 2006. Reported means were back transformed from square root transformed data.

Seeds/m^2	Mean *B.curtipendula*/m^2 2005	Mean *B.curtipendula*/m^2 2006
0	0.50 (±0.38)	0.00 (±0.00)
22	4.50 (±1.13)	2.50 (±1.25)
43	5.88 (±2.04)	4.63 (±1.91)
173	18.50 (±6.74)	19.00 (±5.13)
345	19.00 (±3.53)	24.00 (±6.29)

B. curtipendula seedlings were sampled in August of 2006. A 3-way ANOVA was used for data analysis (Appendix 7). There was a significant difference ($p<0.001$) between blocks for the total number of *B. curtipendula*. A mean of 15.40 (±3.93) was calculated for seedlings sampled in Block 1. A mean of 4.65 (±1.30) was calculated for seedlings of *B. curtipendula* in Block 2 (Table 7).

Mowing significantly increased ($p=0.005$) on the number of *B. curtipendula* seedlings (Appendix 7). There was a mean of 6.50 (±2.029) *B. curtipendula* seedling in no mow plots, while a mean of 13.550 (±3.845) seedlings in mowed plots (Figure 7). A repeated measure analysis was used to look at the effect of mowing on the various seeding rates of *B.curtipendula* between year one and year two. Mowing was shown to have a significant impact, especially in the higher seeding rates between year one and year two, compared to no mow treatments (Table 9).

Varying seeding rates of *B. curtipendula* did have a significant effect ($p<0.001$) on the establishment of *B. curtipendula* (Table 8). There were no significant differences between the 0, 22, and 43 seeds/m^2 seeding rates. There were significant differences however between 345 seeds/m^2 and all other seeding rates except 173 seeds/m^2 (Table 10).

Table 9: Mean number of *B.curtipendula*/m^2 by various seeding rates per mowing treatments in September of 2005 and August of 2006.

Seeding Rate	No mow 2005	Mow 2005	No mow 2006	Mow 2006
0	0.25(±0.25)	0.43(±0.43)	0.00(±0.00)	0.00(±000)
22	2.03(±0.36)	1.78(±0.66)	1.75(±0.48)	3.25(±2.60)
43	2.05(±0.77)	1.90(±0.86)	2.00(±1.10)	7.25(±3.35)
173	4.25(±1.10)	3.19(±1.30)	13.50(±5.74)	24.50(±8.35)
345	4.63(±0.32)	3.73(±0.88)	15.25(±5.10)	32.75(±10.38)

Table 10: Tukey's means test of comparison between varying seeding rates of *B.curtipendula* in September 2005.

Matrix of pairwise comparison probabilities:

	0	22	43	173	345
0	1.000				
22	0.366	1.000			
43	0.135	0.978	1.000		
173	0.000*	0.007*	0.030*	1.000	
345	0.000*	0.000*	0.002*	0.845	1.000

* significant differences

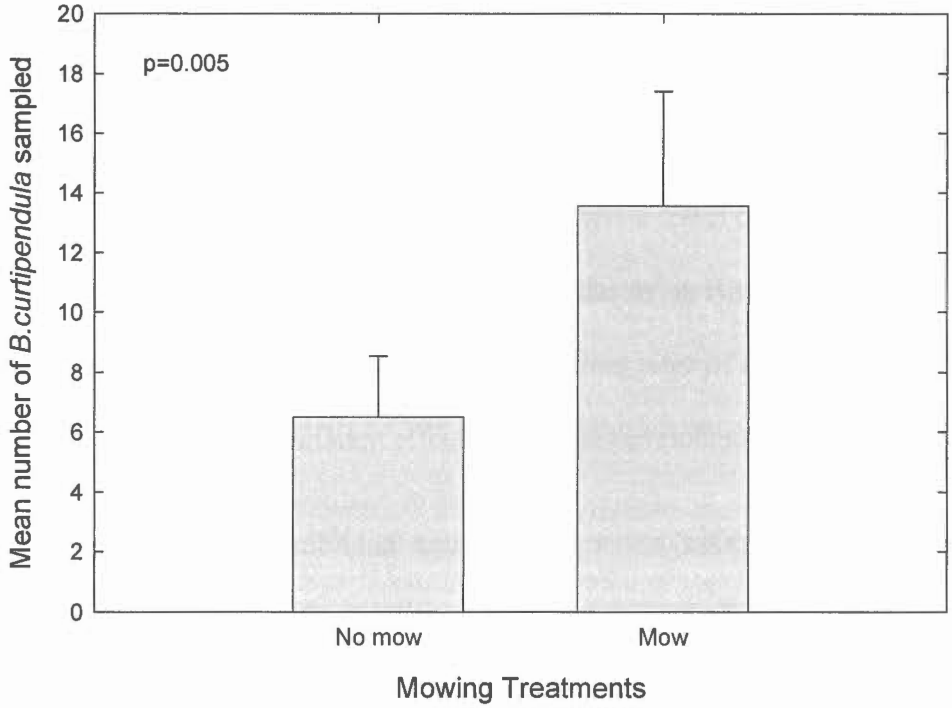


Figure 4: *B. curtipendula* seedlings per mowing treatment in August of 2006.

Species Richness

Species richness for natives in September of 2005 was determined by the number of different native species (excluding *B. curtipendula*) found in each plot. A 3-way ANOVA was used to analyze this data (Appendix 7). There were significant differences ($p<0.001$) in species richness between blocks. There was a mean of 6.75 (±2.49) species/m^2 in Block 1 and a mean of 2.35 (±1.79) species/m^2 in Block 2 (Table 11). Neither mowing ($p=0.141$) or varying seeding rates of *B. curtipendula* ($p=0.579$) (Appendix 7) had significant effects on the species richness of natives.

Species richness for natives in August of 2006 was determined by the number of different native species (excluding *B. curtipendula*) observed in each plot. A 3-way ANOVA was used to analyze this data (Appendix 7). There were significant differences ($p<0.001$) in species richness between blocks. There was a mean of 11.15 (±0.38) species/m^2 in Block 1 and a mean of 7.8 (±0.53) species/m^2 in Block 2 (Table 11). As with 2005, neither mowing ($p=0.835$) or varying seeding rates of *B. curtipendula* ($p=0.940$) (Appendix 7) had a significant effect on the species richness of natives.

The mean number of individual native grass species (except *B. curtipendula)* was compared between samples of September of 2005 and August of 2006 (Table 12). Two of the five species of grasses switchgrass *(Panicum virgatum)*, and Indian grass (*Sorghastrum nutans*) declined from 2005 to 2006. In 2005 an average 0.23 plants/m^2 of switchgrass were sampled but no plants were present in 2006 (Table 12). In 2005 an average of 0.09 plants/m^2 of Indian grass were sampled but only 0.033 plants/m^2 were present in 2006 (Table 12).

Three of the five species of grasses, Canada wild rye (*Elymus canadensis)*, big bluestem (*Andropogon gerardii),* and little bluestem (*Schizachyrium scoparium),* increased from 2005 to 2006. In 2005 an average of 1.50 plants/m^2 of Canada wild rye were present while 7.26 plants/m^2 were present in 2006 (Table 12). Big bluestem averaged 0.50 plants/m^2 present in 2005, and 0.89 plants/m^2 present in 2006 (Table 12). Little bluestem had an average of 0.14 plants/m^2 in 2005 and 0.23 in 2006 (Table 12).

The mean number of individual native forbs was compared between September of 2005 and August of 2006 (Table 13). Three of the fourteen species declined from 2005 to 2006. These were showy tick trefoil (*Desmodium canadense),* roundheaded bushclover (*Lespedeza capitata)*, and purple prairie clover (*Dalea purpurea)* (Table 13).

Of the species that increased, all but butterfly milkweed (*Asclepias tuberosa)* more than doubled the number of plants by the second year (Table 13). This is a total increase of 60% for all native forbs from 2005 to 2006. The other ten species that increased between 2005 and 2006 did so by more that 100%.

Table 11: Species Richness of natives per research block in September of 2005 and August of 2006. Reported means were back transformed from square root transformed data.

Year	Block 1	Block 2	p value
Species/m^2 September 2005	6.75 (±2.49)	2.35 (±1.79)	p<0.001*
Species/m^2 August 2006	11.15 (±0.38)	7.80 (±0.531)	p<0.001*

*significantly different

Table 12: Mean number of native grasses in September of 2005 and August of 2006.

Grass Species	Seeds Sown (m^2)	2005 Natives (m^2)	2006 Natives (m^2)
Canada wild rye (*Elymus canadensis)*	22	1.50	7.26
Big Bluestem (*Andropogon gerardii)*	22	0.50	0.89
Little Bluestem (*Schizachyrium scoparium)*	22	0.14	0.23
Switchgrass (*Panicum virgatum)*	22	0.23	0.0
Indian Grass (*Sorghastrum nutans)*	22	0.09	0.033

Table 13: Mean number of native forbs seedlings in September of 2005 and August of 2006.

Forb Species	Seeds Sown (m^2)	2005 Natives (m^2)	2006 Natives (m^2)
Ox eye sunflower (*Heliopsis helianthoides)*	22	0.42	3.96
Golden Alexanders (*Zizia aurea)*	22	0.00	3.3
Showy Tick Trefoil (*Desmodium canadense)*	22	3.01	2.64
Thimbleweed (*Anemone cylindrical)*	22	0.25	2.20
Black-eyed Susan (*Rudbeckia hirta)*	22	0.37	1.32
Pale Purple Coneflower (*Echinacea pallida)*	22	0.15	1.21
Grayheaded Coneflower (*Ratibida pinnata)*	22	0.45	1.21
Wild Bergamot (*Monarda fistulosa)*	22	0.33	1.21
Round headed Bushclover (*Lespedeza capitata)*	22	0.96	0.55
Stiff Goldenrod (*Solidago rigida)*	22	0.02	0.44
Wild White Indigo (*Baptisa lacteal)*	22	0.00	0.33
Compass Plant (*Silphium laciniatum)*	22	0.00	0.22
Purple Prairie Clover (*Dalea purpurea)*	22	0.25	0.044
Butterfly Milkweed (*Asclepia tuberosa)*	22	0.02	0.033

Species richness for weeds in September of 2005 and August of 2006, was determined by the number of different weed species found in each plot. A 3-way ANOVA was used to analyze this data (Appendix 7). There were significant differences ($p<0.001$) in species richness of weeds between blocks. There was a mean of 0.90 (±0.03) species/m^2 in Block 1 and a mean of 1.41(±0.04) species/m^2 in Block 2 (Table 14). Mowing treatments had no significant effect ($p=0.446$) on the species richness of weeds (Appendix 7). Varying seeding rates of *B. curtipendula* had no significant effect ($p= 0.760$) on the species richness of weeds (Appendix 7). There were no significant differences between blocks, mowing treatments, or seeding rates for species richness in August of 2006 (Appendix 7).

Table 14: Species richness of weeds per research block in September of 2005 and August of 2006. Values are species/m^2.

	Block 1	Block 2	p value
September 2005	0.90 (±0.03)	1.41 (±0.04)	p<0.001*
August 2006	0.75 (±0.03)	0.74 (±0.02)	p= 0.783

*significant difference

Simpson's Index of Dominance

Simpson's Index of Dominance was calculated as the ratio between the number of individuals per the total species sampled in each plot in September of 2005. This data was analyzed with a 3-way ANOVA (Appendix 7). No significant differences ($p=0.652$) were found between research blocks in September of 2005 (Appendix 7).

There was a significant difference ($p=0.015$) in species dominance between mowing and non-mowing (Appendix 7). The mean value for the Simpson's Index of Dominance for no mow plots was 0.763 (±0.028) and 0.592 (±0.070) for mowed plots (Figure 5). There was no significant difference ($p=0.20$) in values for the Simpson's Index of Dominance among seeding rates of *B. curtipendula* (Appendix 7).

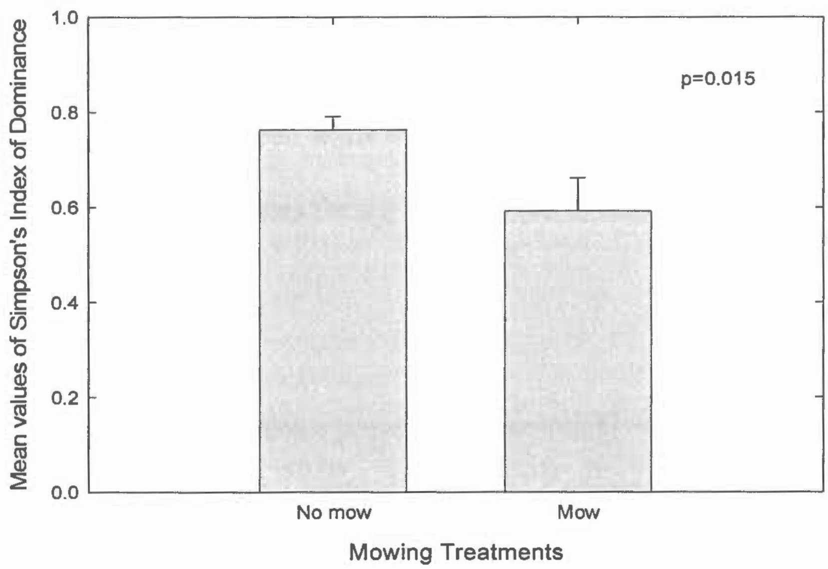


Figure 5: Mean Simpson's Index of Dominance of natives per mowing treatment in September of 2005

Simpson's Index of Dominance was calculated as the ratio between the number of individuals per the total species sampled in each plot in August of 2006. This data was analyzed with a 3-way ANOVA (Appendix 7). There were no significant differences (p=0.881) between research blocks. Simpson's Index of Dominance showed no significant differences (p=0.911) between mowing treatments (Appendix 7). There were no significant differences (p=0.244) in Simpson's Index of Dominance among seeding rates of *B. curtipendula* for (Appendix 7).

Weed Presence

There were significant differences between blocks in 2005 for green amaranth, foxtail, and smartweed (Appendix 7). Block 1 had 95% green amaranth, 20.3% foxtail, 15% Buttonweed and 0.7% smartweed (Table 15). Block 2 had 77.3% green amaranth, 87.3% foxtail, 14.3% buttonweed, and 7.7% smartweed (Table 15). Mowing was only significant (p=0.042) for smartweed with 6.3% of the quadrats in the no mow plots containing smartweed while only 2% of mowed plots, had smartweed (Appendix 7). No significant differences for any of the weed species were seen among the seeding rates (Appendix 7).

Table 15: Weed species present per research block in 2005 by % of quadrats observed.

	Block 1	Block 2	pvalue
Green Amaranth	95.0%	77.3%	0.001*
Foxtail	20.3%	87.3%	<0.001*
Buttonweed	15.0%	14.3%	0.917
Smartweed	0.7%	7.7%	<0.001*

*significantly different

There were significant differences between blocks in 2006 for foxtail, marestail, and smartweed (Appendix 7). Block 1 had 94% foxtail, 7% marestail, and 0.7% smartweed (Table 16). Block 2 had 100% foxtail, 2% marestail, and 4.7% smartweed (Table 16). No significant differences were seen among mowing treatments for any of the weed species (Appendix 7). Smartweed showed significant differences (p= 0.017) between seeding rates (Appendix 7). The differences were between the 22 seeds/m^2 seeding rate and the 173 seeds/m^2 and 345 seeds/m^2 seeding rates (Table 17 and 18). All other seeding rates were statistically similar to each other (Table 17 and 18).

Table 16: Weed species present per research block in 2006 by % of quadrats observed.

	Block 1	Block 2	pvalue
Foxtail	94.0%	100.0%	0.013*
Marestail	7.0%	2.0%	0.033*
Smartweed	0.7%	4.7%	0.046*

*significant differences

Table 17: Tukey's means test of comparison between varying seeding rates of *B.curtipendula* and smartweed presence in August 2006.

Matrix of pairwise comparison probabilities:

	1	2	3	4	5
1	1.000				
2	0.186	1.000			
3	1.000	0.186	1.000		
4	0.742	0.012*	0.742	1.000	
5	0.742	0.012*	0.742	1.000	1.000

* significant differences

Table 18: Mean percentage of sample areas that contained smartweed among varying seeding rates of *B.curtipendula* in August 2006.

	0 seeds/m^2	22 seeds/m^2	43 seeds/m^2	173 seeds/m^2	345 seeds/m^2
smartweed	0.38(0.26)	1.25 (0.45)	0.38(0.26)	0.00(0.0)	0.00(0.0)

In 2005, only 4 weed species were found in 4% or more of the quadrats sampled (Table 19). In 2006, only 2 weed species were found in 4% or more of the quadrats sampled (Table 19). Between 2005 and 2006, the presence of three weed species decreased. These species were green amaranth, buttonweed, and smartweed (Table 19). Two species, foxtail and marestail, actually increased between 2005 and 2006 (Table 19).

Table 19: Weed species that were present in 4% or more of the quadrats in the research area in 2005 and 2006.

	Green Amaranth	Foxtail	Buttonweed	Smartweed	Marestail
2005	86.2%	53.8%	14.7%	4.2%	0.0%
2006	0.7%	97%	0.2%	2.7%	4.5%

Native Plant Biomass

There was a significant difference ($p<0.001$) in total native plant biomass between blocks (Appendix 7) for the September 2005 sampling. There was a mean of 0.134 (±0.032) grams/m^2 of total native biomass for Block 1 and a mean of 0.01 (±0.003) grams/m^2 of total native biomass for Block 2 (Table 20).

There was no significant difference ($p=0.772$) in total native plant biomass between mowing treatments (Appendix 7). Similarly, no significant differences ($p=0.853$) were observed in total native biomass among varying seeding rates of *B. curtipendula* treatments (Appendix 7). There was, however, a significant difference in total native biomass ($p=0.033$) observed in the interaction between research block and mowing treatments (Appendix 7).

Table 20: Mean total native biomass in grams and standard errors per research block in September of 2005 and August of 2006. Reported means were back transformed from square root transformed data.

	Block 1	Block 2	p value
September 2005	0.134 (±0.032) grams/m^2	0.01 (±0.003) grams/m^2	p<0.001 *
August 2006	16.156 (±4.563) grams/m^2	4.571 (±1.198) grams/m^2	p<0.001 *

* significant difference

There was a significant difference ($p<0.001$) in total native plant biomass between blocks for the August 2006 sampling (Appendix 7). There was a mean of 16.156 (±4.563) grams of total native biomass in Block 1 and a mean of 4.571 (±1.198) grams of total native biomass in Block 2 (Table 20).

There was a significant difference ($p<0.001$) in total native plant biomass between mowing treatments (Appendix 7). A mean of 18.678 (±4.284) grams was calculated for total native biomass sampled in the no mow treatments (Figure 6). A mean of 2.05 (±0.395) grams of total native biomass was determined in the mow treatments (Figure 6). No significant differences ($p=0.149$) were found among varying seeding rate of *B. curtipendula* (Appendix 7).

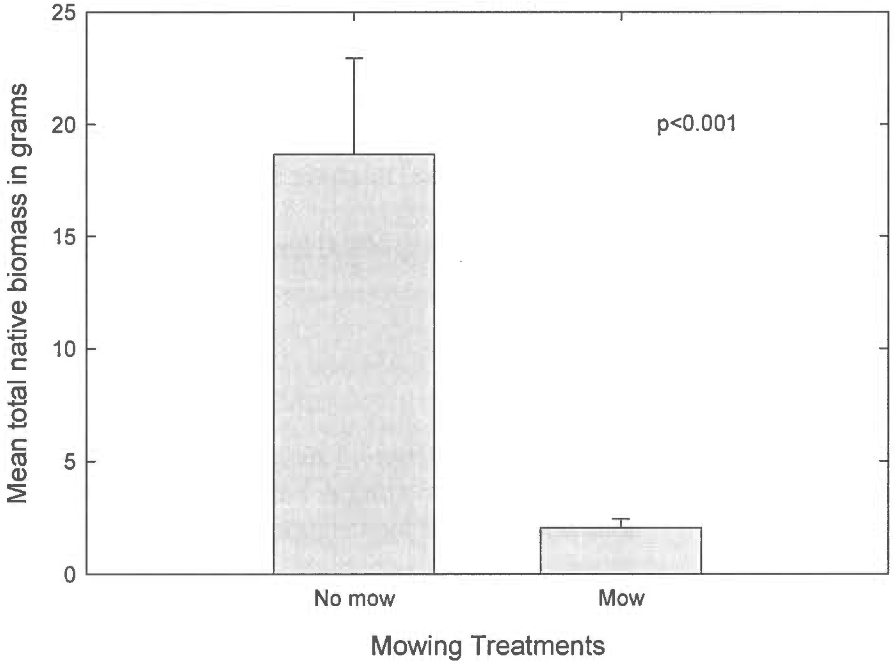


Figure 6: Mean total native biomass per mowing treatment sampled in August of 2006.

Native Grass Biomass

There was a significant difference for September 2005 ($p<0.001$) in total native grass biomass between blocks (Appendix 7). The mean of total native grass biomass was 0.057 (±0.025) grams in Block 1 and 0.003 (±0.003) grams of total native grass biomass in Block 2 (Table 21).

Mowing did not significantly ($p=0.68$) affect native grass (excluding *B. curtipendula)* biomass. There were significant differences ($p=0.018$) in biomass among the varying seeding rates of *B. curtipendula* (Table 20). These significant differences were mainly due to three way treatment interactions between mowing, seeding rate, and block effects (Appendix 7).The mean of total native grasses sampled was 0.006 (±0.003) grams in 0 seeds/m^2 seeding treatment of *B. curtipendula,* while it was 0.008 (±0.007) grams in the 22 seeds/m^2 seeding treatment (Table 22). The mean of total native grasses was 0.012(±0.01) grams in 43 seeds/m^2 seeding treatment, 0.032 (±0.018) grams in 173 seeds/m^2 seeding treatment, and 0.094 (±0.061)grams in 345 seeds/m^2 seeding treatment (Table 22).

Table 21: Mean total native grass biomass in grams and standard errors per research block in September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data.

	Block 1	Block 2	p values
September 2005	0.057 (±0.025)	0.003 (±0.003)	p<0.001*
August 2006	13.47 (±4.36)	3.73 (±1.14)	p<0.001*

* significantly different

Table 22: Mean total native grass biomass in grams per varying seeding rate of *B.curtipendula* in September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data.

	0 seeds/m^2	22 seeds/m^2	43 seeds/m^2	173 seeds/m^2	345 seeds/m^2	p value
September 2005	0.006 (±0.003)	0.008 (±0.007)	0.012 (±0.01)	0.032 (±0.018)	0.094 (±0.061)	p=0.018 *
August 2006	4.323 (±2.79)	14.83 (±7.83)	4.15 (±1.97)	12.893 (±7.84)	6.798 (±2.45)	p=0.022 *

* significantly different

There was a significant difference ($p<0.001$) in total native grass biomass between blocks (Appendix 7) for the August 2006 sampling. There was a mean of 13.47 (±4.36) grams of total native grass biomass in Block 1 and a mean of 3.73 (±1.14) grams of total native grass biomass in Block 2 (Table 21).

A significant difference ($p<0.001$) in total native grass biomass was observed between mowing treatments (Appendix 7). A mean of 16.394 (±4.036) grams was calculated for total native biomass in the no mow treatments (Figure 7). A mean of 0.803 (±0.29) grams of total native biomass was calculated in the mowed treatments (Figure 7).

Significant differences ($p=0.022$) were found in varying seeding rates of *B. curtipendula* (Table 22). These significant differences were mainly due to three way interaction between block, mowing, and seeding rate treatments (Appendix 7). There was a mean of 4.323 (±2.79) grams/m^2 of total native grasses in 0 seeds/m^2 seeding treatment of *B. curtipendula* (Table 22). There was a mean of 14.83 (±7.83) grams/m^2 of total native grasses in 22 seeds/m^2 seeding treatment of *B. curtipendula* (Table 22). There was a mean of 4.15 (±1.97)grams/m^2 of total native grasses in 43 seeds/m^2 seeding treatment of *B. curtipendula* (Table 22). There was a mean of 12.893 (±7.84) grams/m^2 of total native grasses in 173 seeds/m^2 seeding treatment of *B. curtipendula* (Table 22). There was a mean of 6.798 (±2.45) grams/m^2 of total native grasses in 345 seeds/m^2 seeding treatment of *B. curtipendula* (Table 22).

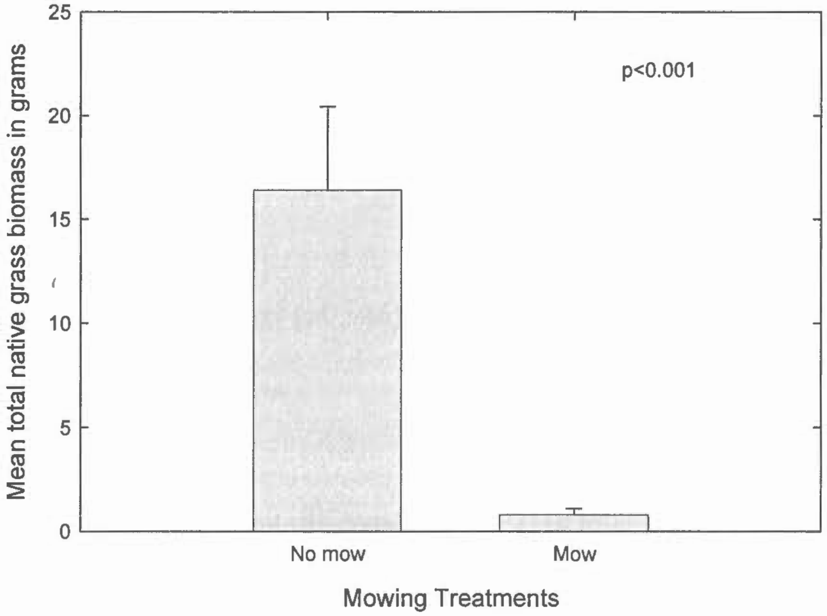


Figure 7: Mean total native grass biomass per mowing treatment sampled in August of 2006.

Native Forb Biomass

There was a significant difference (p<0.001) in total native forb biomass between blocks (Appendix 7) for the September 2005 sampling. There was a mean mass of 0.217 (±0.058)grams of total native forb biomass in Block 1 and a mean mass of 0.017 (±0.007) grams of total native forb biomass in Block 2 (Table 23).

No significant differences (p=0.874) in total native forb biomass were seen among varying seeding treatments of *B. curtipendula* (Appendix 2). Mowing treatments showed no significant differences (p=0.795) for total native forb biomass (Appendix 7).

Table 23: Mean total native forb biomass in grams and standard errors per research block in September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data.

	Block 1	Block 2	p value
September 2005	0.217 (±0.058)	0.017 (±0.007)	p<0.001 *
August 2006	2.69 (±0.946)	0.841 (±0.171)	p=0.02 *

*significantly different

There was a significant difference (p=0.02) in total native forb biomass between blocks (Appendix 7) for the August 2006 sampling. There was a mean mass of 2.689 (±0.946) grams of total native forb biomass in Block 1 and a mean mass of 0.841 (±0.171) grams of total native forb biomass in Block 2 (Table 23). No significant differences (p=0.584) in total native forb biomass were observed among varying seeding treatments of *B. curtipendula* (Appendix 7). Mowing treatments showed no significant differences (p=0.471) for total native forb biomass (Appendix 7).

B.curtipendula Biomass

There was a significant difference (p<0.001) in total *B.curtipendula* biomass between blocks (Appendix 7) for the September 2005 sampling. There was a mean of 0.416 (±0.14) grams of *B. curtipendula* biomass in Block 1 and a mean of 0.28 (±0.01) grams of *B. curtipendula* biomass in Block 2 (Table 24). There was a significant difference (p=0.003) in total biomass of *B. curtipendula* among varying seeding rate treatments of *B. curtipendula* (Appendix 7 and Table 25). The significant differences were due to an interaction between the block and seeding rate treatments (Appendix 7). No significant differences (p=0.520) were seen among mowing treatments for the total amount of *B. curtipendula* biomass sampled (Appendix 7).

Table 24: Mean total *B. curtipendula* biomass in grams and standard errors per research block in September of 2005 and August of 2006. Biomass was significantly (p<0.001) different for September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data

	Block 1	Block 2	p value
September 2005	0.416 (±0.14)	0.28 (±0.01)	p>0.001 *
August 2006	4.05 (±1.11)	0.52 (±0.18)	p>0.001 *

* significantly different

Table 25: Mean total *B. curtipendula* biomass sampled per varying seeding rate of *B.curtipendula* in September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data.

	0 seeds/m^2	22 seeds/m^2	43 seeds/m^2	173 seeds/m^2	345 seeds/m^2	p value
September 2005	0.012 (±0.01)	0.74 (±0.024)	0.142 (±0.102)	0.444 (±0.187)	0.439 (±0.314)	p=0.003 *
August 2006	0.00 (±0.00)	0.892 (±0.463)	1.64 (±0.992)	4.66 (±2.11)	4.23 (±1.66)	p=0.001 *

* significantly different

There was a significant difference ($p<0.001$) in total *B.curtipendula* biomass between blocks for (Appendix 7) for the August 2006 sampling. There was a mean of 4.05 (±1.11) grams of *B. curtipendula* biomass in Block 1 and a mean of 0.52 (±0.18) grams of *B. curtipendula* biomass in Block 2 (Table 24). No significant differences ($p=0.057$) were seen among mowing treatments for the total amount of *B. curtipendula* biomass sampled (Appendix 7).

There were significant differences ($p=0.001$) in total biomass of *B. curtipendula* among varying seeding rate treatments of *B. curtipendula* (Appendix 7). Significant differences were seen between the 0 seeds/m^2 which had a mean of 0(0.00) grams of *B. curtipenula* biomass and the seeding rates of 173 seeds/m^2 which had 4.66 (±2.11)grams of biomass and 345 seeds/m^2 which had 4.23 (±1.66)grams of biomass (Table 25 and Table 26). No significant differences were seen between any of the other seeding rates (Table 25 and Table 26).

Table 26: Tukey's means test of comparison between varying seeding rates of *B.curtipendula* in August 2006.

Matrix of pairwise comparison probabilities:

	0	22	43	173	345
0	1.000				
22	0.661	1.000			
43	0.445	0.997	1.000		
173	0.010*	0.213	0.377	1.000	
345	0.010*	0.214	0.378	1.000	1.000

* significant differences

Weed Biomass

There was a significant difference ($p=0.045$) in total weed biomass between blocks (Appendix 7) for the September 2005 sampling. There was a mean of 41.942 (±6.892) grams of weed biomass in Block 1 and a mean of 34.164 (±4.852) grams of weed biomass in Block 2 (Figure 8).

There was a significant difference ($p<0.001$) in total weed biomass between mowing treatments (Appendix 7). There was a mean of 62.372 (±3.062) grams of total weed biomass in the no mow treatments, and a mean of 13.733 (±0.998) grams of total weed biomass in the mowed treatments (Figure 9). There were no significant differences ($p=0.166$) (Appendix 7) in total weed biomass among the varying seeding rate treatments (Table 27).

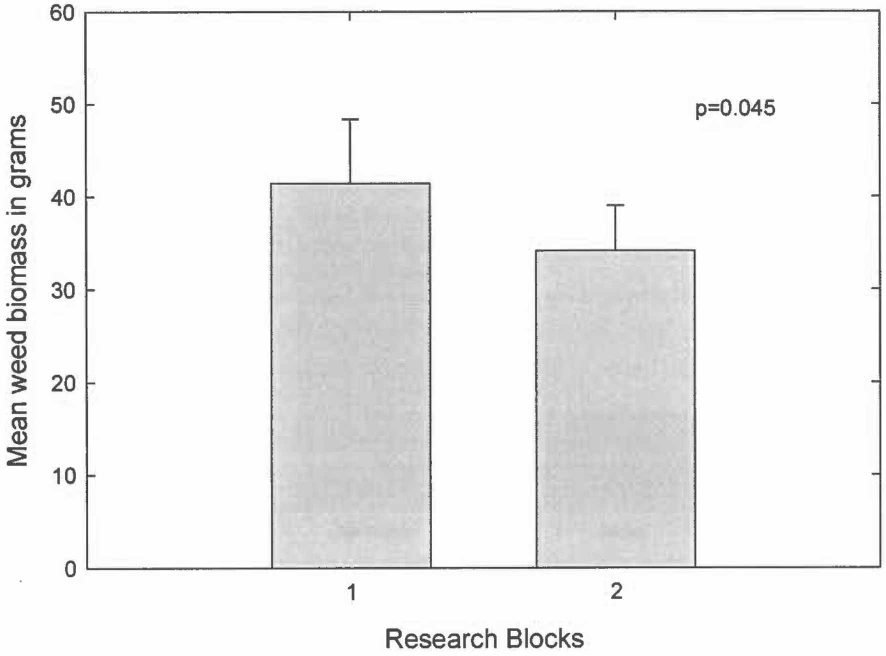


Figure 8: Mean total weed biomass per research blocks in September of 2005.

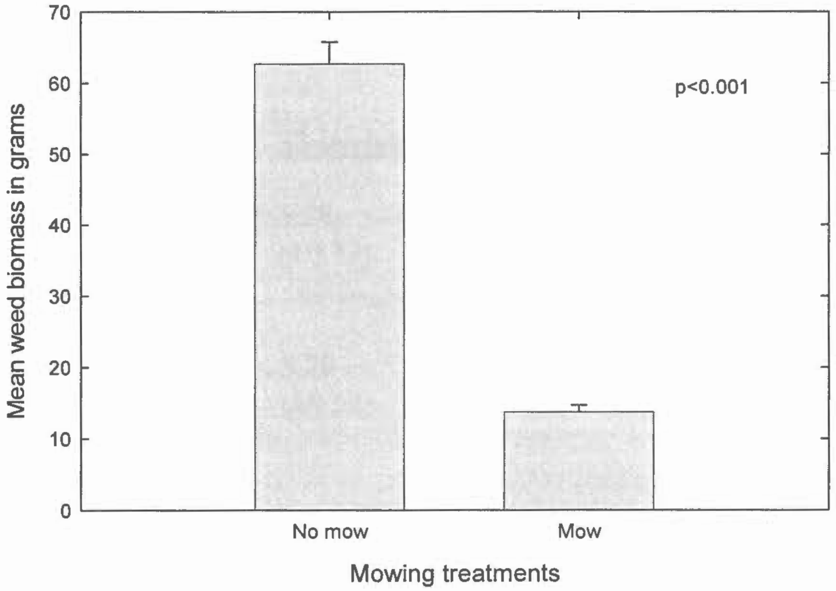


Figure 9: Mean total weed biomass per mowing treatment sampled in September of 2005.

There were no significant differences (p=0.095) in total weed biomass between blocks (Appendix 7). Mowing treatments showed no significant difference (p=0.658) for total weed biomass (Appendix 7). There were no significant differences (p=0.167) (Appendix 7) among varying seeding rates of *B. curtipendula* for weed biomass (Table 27).

Table 27: Mean total weed biomass per varying seeding rate of *B.curtipendula* in September of 2005 and August of 2006. All reported means are in grams/m^2 and were back transformed from square root transformed data.

	0 seeds/m^2	22 seeds/m^2	43 seeds/m^2	173 seeds/m^2	345 seeds/m^2	p value
September 2005	6.09 (±1.03)	5.78 (±0.77)	6.01 (±0.73)	5.33 (±0.74)	5.55 (±0.86)	0.166
August 2006	6.52 (±0.46)	5.29 (±0.52)	6.29 (±0.70)	5.04 (±0.31)	5.17 (±0.25)	0.167

Root and Shoot Biomass of *B. curtipendula*

Data was collected from *B. curtipendula* root cores in August of 2006. There was no significant difference (p=0.523) in total root biomass between research blocks (Appendix 7). Varying seeding rate of *B. curtipendula* had no significant difference (p=0.155) on the total root biomass (Appendix 7). There were no significant differences (p=0.687) for total root biomass among mowing treatments (Appendix 7).

One inch shoot samples were cut from root cores in August of 2006. There was no significant difference (p=0.734) in total shoot biomass between research blocks for (Appendix 7). Varying seeding rate of *B. curtipendula* had no significant difference (p=0.776) on the total shoot biomass (Appendix 7). There were no significant differences (p=0.139) for total shoot biomass among mowing treatments (Appendix 7).

CHAPTER 4

DISCUSSION

Reducing weeds early in prairie reconstruction can aid in establishment of native species. This study tested the effectiveness of a native warm season grass species, *Bouteloua curtipendula*, as a nurse crop in the establishment of a native prairie planting. Effective nurse crops emerge and grow rapidly to occupy space in the planted area prior to weedy annuals. By out-competing, and thus reducing weeds, nurse crops aid post planting establishment and growth of native species. They also deter erosion of the soil substrate by intercepting rainfall and reducing the impact of raindrops on the soil and anchoring soil with their roots. Kurtz (1994) demonstrated that mowing weeds in the first growing season after seeding reduced weed canopy and enhanced native species establishment. The effectiveness of *Bouteloua curtipendula*, in weed reduction and prairie establishment was compared with post-seeding mowing.

I hypothesized that an increase in the seeding rate of a nurse crop, side-oats grama (*Bouteloua curtipendula)*, would result in an increase in both native plant numbers and diversity. There were overall more native plants present in 2006 than in 2005. However, varying seeding rates of the nurse crop had no significant effect on the establishment, native species richness or species dominance in the first two years after planting (Appendix 7).

Although there were no differences for actual plant numbers, the nurse crop did influence the amount of above ground plant growth or biomass of native grasses the first year (Appendix 7) (Table 22). The lowest seeding rates of the nurse crop had the lowest amounts of biomass for native grasses and the highest rate of nurse crop had the highest amount of biomass. This supports the hypothesis that the greater the seeding rates of nurse crop the more natives that will be established. However, this difference was not observed the second year (Table 22). Although no significant differences were seen among the research treatments, statistical interactions between block, mowing, and seeding rate treatments were observed (Appendix 7). This suggests that seeding rate may be having some effect, but it may have been too early in the reconstruction to discern the specific interactions.

Native plant establishment was not affected in a positive or negative way by the varying nurse crop seeding rates. This supports the hypothesis that *B.curtipendula* can be used as a nurse crop without an adverse effect on native plant establishment. However, it does not support the hypothesis that it increases native species establishment. Major differences this early in a reconstruction may not be observed, as many of the natives are still finding their niche in a new environment. Betz (1984) found that reconstructions often took up to four years to establish enough native biomass, usually grasses, to provide fuel for a fire. I suspect that sampling in later years should provide more definitive results.

Seeding rates had no significant effect on the species of weeds in the first year (Appendix 7, Table 15), but smartweed significantly declined among the higher seeding rates in the second year. The greatest number of smartweed was present in plots with a seeding rate of 22 seeds/m^2. No smartweed was present in the 173 and 345 seeds/m^2

seeding rate treatments (Table 16). This suggests that smartweed can not establish or compete with the nurse crop at higher seeding rates. However, due to the small amount of smartweed that was present throughout the entire research site such a conclusion is tentative at best. If higher amounts of smartweed had been present this conclusion would have more validity.

Seeding rate of *B. curtipendula* had no significant effect on the amount of weed biomass (Table 27). Many of these annual weeds are broadleaf types which could give them an edge in competing for resources especially with a nurse crop like *B. curtipendula* which is somewhat smaller in stature. This is similar to the observation that native forb biomass wasn't affected by seeding rate treatments and didn't diminish in numbers from 2005 to 2006.

Due to time constraints in sampling, presence or absence of weed species was recorded rather than counting individual plants. This provides information about the frequency of the various species of weeds, but not about the coverage of each of those species. By only recording if a species was present in the sampled quadrat and not counting the quantity of individuals in that space, we may have missed some important information on what was really occurring with regard to the nurse crop's ability to out compete weedy plants. This could account for the fact that weeds were not affected by the varying seeding rates of the nurse crop. We relied heavily on biomass data to provide this information and that may not have been enough to gain a good perspective on what was actually occurring. These findings did not support the hypothesis that at a high enough seeding rate *B. curtipendula* would reduce weedy competition.

Varying seeding rates of *B. curtipendula* did have a significant effect on its establishment. It would be expected that if twice as many seeds were planted then twice as many plants would establish. Establishment increased as seeding rate increased, but at the high seeding rates of 173 and 345 seeds/m^2 there was no significant increase in establishment. Launchbaugh's (1970) study noted that although plant numbers increased significantly with increased seeding rate, the overall number of plants was low compared with the seeding rates. Perhaps at higher seeding rates of *B. curtipendula* the plants began competing with themselves for limited resources. Available resources would have been stretched by increased numbers of *B.curtipendula* seedlings, as well as native seedlings, and weedy annuals from the seedbank. The Launchbaugh (1970) study suggests that soil moisture from precipitation was a major factor in limiting plant numbers with increased seeding rates. However, precipitation for the two years of the study was normal (Hillaker 2009), so it is doubtful that this was a limiting factor. Predation may have been another factor at the higher seeding rates. Grain eating animals such as small mammals, bird, and insects may have been attracted to the larger quantitiy of seed present at higher seeding rates of *B. curtipendula.*

B. curtipendula didn't produce a lot of biomass especially during the first growing season. Even at the highest seeding rates, there was a mean of less than 0.5 grams of dried biomass of *B. curtipendula* (Table 25). The mean amount of biomass sampled in plots with seeding rates of 22 and 43 seeds/m^2 was higher in year two than would be expected considering that fewer plants were present at these seeding rates in year two (Table 8).

The increased biomass from fewer plants was seen to an even greater extent at the higher seeding rates of 173 and 345 seeds/m^2. In both cases the mean number of plants increased very slightly from year one to year two, while the amount of biomass increased dramatically (Table 8 and Table 25). This suggests that the plants were more robust the second year than they had been the previous year. Apparently *B. curtipendula* requires two years for good establishment. This seemingly slow rate of establishment is not a desirable trait for a nurse crop.

This study suggests that a resource manager planting *B. curtipendula* as a nurse crop will get the best return in terms of establishment and biomass at a rate of 173 seeds/m^2. As noted above, the rate of establishment of *B. curtipendula* both in terms of numbers of actual plants or amount of biomass seemed to be slow for the a good nurse crop. Perhaps the biomass increase may be a benefit for future fire management. Wilsey (2005) indicated that *B.curtipendula* and *Elmus canadensis* used as cover crops provided sufficient biomass for a fuel load that allowed plots to be burned more thoroughly and at much higher temperatures. He observed that the fire seemed to reduce exotic species such as smooth brome (*Bromus inermis)* and crown vetch (*Coronilla varia)*.

The seeding rate comparisons indicate that *B. curtipendula* is not a good nurse crop. Lower seeding rates do not result in sufficient establishment or biomass for the nurse crop to be effective in reducing weed pressure, helping natives establish, or providing biomass fuel to be used in a burn management plant to reduce weeds. Furthermore, the increased cost of higher seeding rates does not result in sufficient establishment or biomass to be worthwhile.

I compared the effect mowing had on native plant establishment, nurse crop establishment, and weed suppression with that resulting from varying seeding rates of the nurse crop. As discussed previously, repeated mowing during the summer after seeding has been shown to suppress weeds and increase native plant establishment (Kurtz 1994). The reduction of weeds by mowing permitted a greater amount of light to reach the surface of the ground and the first year seedlings. Kurtz conjectured that the increased light enhanced photosynthesis of the native species and enabled them to establish more readily. In this experiment, more light certainly did reach ground level as a result of mowing, 5 times more in 2005 and 3 times more in 2006. However, there was no significant increase in establishment of native species the first year. This may have been due unanticipated difficulties in carrying out the experiment as designed. After a very slow start, the weeds grew more rapidly than expected from July to August. Consequently there was only one opportunity to mow the site two weeks before sampling. The rapid weed growth may have created a canopy and shaded the treatments at a crucial time or the short time between mowing and sampling may have been insufficient to permit development of discernable differences between the treatments. In any event, due to limited weed suppression, I was unable to identify any effect of mowing on native species establishment that year.

In the second year there were some interesting differences in species composition of the prairie planting resulting from mowing. Significantly more total natives were observed in the no mow plots than in those that were mowed. The reduction in native species from mowing occurred in the native grasses. There were about 5 times more native grasses in the no mow plots than in the mowed ones (Table 3). On the other hand, though native forbs were not significantly affected by mowing, about 12% more forbs were present in the mowed plots than the unmowed (Table 5). These results are similar to those of Williams et. al (2007), where mowing was used to successfully establish forbs in a well developed stand of native grasses. They found that a single year of frequent mowing greatly increased the number of forbs planted into the grass stand the previous fall while decreasing the density of the existing native grasses.

According to Simpon's Index of Dominance (2005) no mow treatments seemed to favor species dominance over mowed treatments. Perhaps this was a result of only one mowing occurring on the site late in the growing season. With multiple mowings in 2006, the Simpons Index of Dominance showed no significant differences in the dominance of any particular species throughout the treatment areas (Appendix 7). The species richness was not affected by mowing in either year (Appendix 7). Perhaps the multiple mowings during the second year helped to increase forbs that were apparently not present during the first season, while allowing those that were present to persist (Table 5 and Table 13).

This trend suggests that mowing may favor forbs over grasses in recently reconstructed prairies as well as established grass stands.

Kurtz (1994) and Williams et. al (2007) noted greater growth of native species, especially forbs, in the mowed areas with increased light. Williams et. al (2007) observed that the plants under the canopy of tall grasses of the unmowed areas were more spindly and less robust than those exposed to more light. However, in first year of this study, the biomass of the native species was not affected by mowing. This, of course, could be due to the effect of the rapid weed growth on native species as discussed previously. In the second year, as might have been expected, there was significantly less biomass (9 times) in the mowed plots than the unmowed. Once again the difference was a result of the response of the native grasses rather than the forbs. Much more native grass biomass (almost 16 times) was present in the no mow plots as opposed to the mow plots. Possibly these results can be attributed to differences in growth patterns of grasses and forbs. If the grasses establish and grow more quickly, they may be cut during mowing treatments whereas slower growing forbs may be beneath the mower blades.

B. curtipendula, apparently responds differently to mowing than the other native grasses. There were no observed differences in response to the mow/no mow treatments in the first year. However, in the second year, mowing resulted in almost twice as many plants (Figure 4). This was especially evident at the highest seeding rates of 173 and 345 seeds/m^2 (Table 9). Although more numerous, the plants were smaller and there was no difference in biomass. This suggests that tillering increases when *B. curtipendua* is mowed. This is consistent with a study by Mintenko (2002). He found that native grasses in the *Bouteloua* genus made good candidates for turf grass, which is frequently mowed. He found that they had excellent drought tolerance, maintained a nice lush color, had limited disease or pest problems, and were highly adaptable to mowing stress.

Mowing had little effect on the species richness of weeds in either year. However, it significantly reduced weed biomass (4.5 times) in the first year, but had no effect in the second year. These could be the result of different types of weeds in the two years. Massive weeds such as green amaranth and buttonweed were the most abundant weeds in the first year whereas, foxtail was most abundant in 2006.

Mowing was more effective at weed reduction than the nurse crop. Mowing seemed to favor native forb establishment more than native grass establishment, but overall had no detrimental effect on native plant establishment. Mowing also seemed to stimulate the growth of the nurse crop itself, especially at the higher seeding rates of 173 and 345 seed/m^2.

Differences in the blocks may have affected the results. Several differences in results of the blocks were observed for the study. These included native plant establishment in 2005 and 2006, *B. curtipendula* establishment in 2005 and 2006, species richness for natives and weeds in 2005, species richness for natives in 2006, weed presence in 2005 and 2006, native plant biomass in 2005 and 2006, *B.curtipendula* biomass in 2005 and 2006, and weed biomass in 2005. Although, the research site was relatively uniform, it did include two different soil types. Three fourths of the site consisted of a Mahaska Series soil which is characterized as a deep loamy deposit that is somewhat poorly drained (NRCS websoilsurvey). The other one fourth was a Taintor

Series soil that is characterized as a deep loamy deposit that is poorly drained. This soil type comprised one-half of research Block 2 and often appeared to be wetter than the rest of the site. Although these two soil types are very similar, the difference in drainage may have been sufficient to account for the consistent differences in block results. These differences may have been sufficient to mask the effects of the nurse crop in controlling weed species and aiding native species establishment.

The differences in mowing in 2005 and 2006 mentioned earlier may have been a factor in influencing the results. A surprisingly rapid growth of weeds in late July resulted in an extensive canopy of weeds on the site in August. The area was mowed on August 21, 2005. Only 2 weeks elapsed between mowing and sampling on September 03, 2005. This was the only mowing treatment the first year. This late mowing probably accounts for the higher level of light measured at the soil surface of the mowed plots in 2005 than in 2006. In 2006 the plots were mowed 4 times at approximately 3 week intervals. The last mowing was done on July 20th and the site was sampled about 4 and one half weeks later on August 15, 2006. This greater amount of elapsed time between mowing and sampling in 2006 allowed more re-growth of vegetation. Thus there was more biomass and canopy cover which reduced surface light.

The seeding date may have been a factor in influencing the results. The site was seeded on June 18, 2005. For most native prairie reconstructions, this is a fairly late planting date. It was expected that warm season grasses would establish with decent success due to the late seeding date being favorable to their growing conditions.

However, very few warm season grasses were found in year one. Big bluestem and little bluestem, increased from year one to year two, but the increase was small (Table 12). Indian grass declined in the second growing season and switchgrass was not even observed (Table 12). It may have been that grass seedlings the first year were shaded by the quick growth of broad leaf weeds. Those that survived the summer may have suffered from winter mortality, or the seeds just remained dormant the first year, germinated the second year, and were shaded out in the plots that were not mowed.

The cool season grass (in the seed mix), Canada wild rye, actually may have benefited from the late seeding date. Of the native grasses, it showed the greatest amount of establishment in the first year of the study (Table 12). It also seemed to increase to a greater degree in the second year, than the rest of the natives grasses and forbs (Table 12 and Table 13). A future study looking at varying seeding dates of warm and cool season grass may help to better answer this establishment question.

I had a limited amount of control over seeding time due to the location of the study. Seeding time was dictated by the availability of the Neal Smith NWR staff. If the seeding had been done a month earlier, the results from the first growing season may likely have been different. An earlier seeding date may have allowed the native plants more time to establish and mature. This may have also led to more mowings in the first growing season. Perhaps a clearer picture of the effects of mowing compared to varying nurse crops seeding rates in the early stages of a reconstruction would have emerged.

As with many field research projects, in retrospect, there are things that one would do differently if given the opportunity. Prior to laying the research blocks out, I should have examined more closely the soil types in the research area. This might have avoided the block differences that were observed throughout this research project. Although the soil types were quite similar, the drainage difference was apparently sufficient to affect both natives and weed species. With the limited amount of area that was available for the research, I may have needed to reduce the block and the plot sizes to ensure that the research area was comprised of one soil type.

The idea of tailoring the seed mix including a nurse crop in the reconstruction process to suppress weeds is fairly new. Work is being done to determine good nurse crops that could be added to seeding mixes to help with weed suppression in early establishment. Mowing still seems to be the favorable management technique in weed reduction in the first years of reconstruction. High seeding rates of native nurse crops may help to add biomass and fuel to a site that could make burning early in a reconstruction easier. This would be especially beneficial if the higher seeding rates do not affect establishment of native species. The suppression of weeds in this complex ecosystem may require more than one method of early management to help insure a more successful planting.

Conclusion

The use of *Bouteloua curtipendula* as a nurse crop in poorly drained deep loamy soils was ineffective in the suppression of weeds and did not affect native establishment in the first two years of a native reconstruction. Mowing was more effective in reducing weeds than the *B. curtipendula* nurse crop. Mowing reduced total native plant establishment, especially native grasses where as native forb establishment was not affected by mowing.

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APPENDIX 1

SPECIES CODE FOR RAW DATA

An ge – *Andropogon gerardii*

El ca – *Elymus canadensis*

So nu – *Sorghastrum nutans*

Sc sc – *Schizachyrium scoparius*

Bo cu – *Bouteloua curtipendula*

Pa vi – *Panicum virgatum*

Ru hi – *Rudbeckia hirta*

As tu – *Asclepias tuberosa*

Si la – *Silphium laciniatum*

Zi au – *Zizia aurea*

Ra pi – *Ratibida pinnata*

Py vi – *Pycanthemum virginianum*

As na – *Aster novae-angliae*

Tr oh – *Tradescantia ohiensis*

He he - *Heliopsis helianthoides*

Ec pa – *Echinacea purpurea*

Co pa – *Coreopsis palmata*

Da pu – *Dalea purpurea*

Er yu – *Erynigium yuccifolium*

Li as – *Liatris aspera*

Le ca – *Lespedeza capitata*

De ca – *Desmodium canadense*

So ri – *Solidago rigida*

An cy – *Anemone cylindrica*

Ba la – *Baptisia leucantha*

Mo fi – *Monarda fistulosa*

APPENDIX 2

SEEDLING COUNT RAW DATA

September 03, 2005

Block	Plot	TRMT	**An ge**	**El ca**	**So nu**	**Sc sc**	**Bo cu**	**Pa vi**	**Ru hi**	**As tu**	**Si la**	**Zi au**	**Ra pi**	**Py vi**	**As na**	**Tr oh**	**He he**	**Ec pa**	**Co pa**	**Da pu**
1	1	1	0	7	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	1
1	2	3	0	2	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	2
1	3	4	0	16	1	0	5	0	1	0	0	0	0	0	0	0	2	0	0	1
1	4	1	5	21	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1
1	5	2	4	6	0	1	0	0	3	0	0	0	1	0	0	0	1	3	0	0
1	6	5	0	5	0	0	7	1	0	0	0	0	0	0	0	0	1	0	0	1
1	7	2	0	1	0	0	0	2	0	0	0	0	4	0	0	0	1	0	0	0
1	8	9	1	4	0	0	24	1	1	0	0	0	3	0	0	0	0	0	0	2
1	9	7	1	0	0	0	37	0	2	0	0	0	1	0	0	0	1	0	0	0
1	10	10	1	2	0	1	28	0	1	0	0	0	1	0	0	0	0	1	0	0
1	11	8	1	4	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	1
1	12	9	1	1	0	0	31	0	0	0	0	0	0	0	0	0	1	0	0	1
1	13	3	0	0	0	0	10	0	0	0	0	0	3	0	0	0	1	0	0	0
1	14	4	5	10	0	0	5	0	1	0	0	0	1	0	0	0	3	1	0	1
1	15	6	0	3	0	0	12	0	2	0	0	0	0	0	0	0	1	0	0	1
1	16	6	2	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
1	17	7	1	0	0	0	22	0	2	1	0	0	0	0	0	0	3	1	0	0
1	18	5	2	0	0	0	15	0	0	0	0	0	1	0	0	0	1	0	0	1
1	19	10	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
1	20	8	1	0	0	0	55	0	2	0	0	0	0	0	0	0	4	0	0	1
		Totals	25	87	2	3	289	4	15	1	0	0	22	0	0	0	21	6	0	14

September 03, 2005

Block	Plot	TRMT	Er yu	Li as	Le ca	De ca	So ri	An cy	Ba la	Mo fi
1	1	1	0	0	3	13	0	0	0	0
1	2	3	0	0	0	7	0	0	0	0
1	3	4	0	0	0	3	0	4	0	1
1	4	1	0	0	1	19	1	2	0	1
1	5	2	0	0	0	5	0	1	0	3
1	6	5	0	0	3	8	0	0	0	1
1	7	2	0	0	1	3	0	0	0	0
1	8	9	0	0	1	9	0	1	0	1
1	9	7	0	0	1	6	0	0	0	1
1	10	10	0	0	4	10	0	3	0	3
1	11	8	0	0	3	6	0	0	0	2
1	12	9	0	0	2	7	0	0	0	0
1	13	3	0	0	2	6	0	0	0	1
1	14	4	0	0	1	10	0	1	0	0
1	15	6	0	0	1	12	0	0	0	0
1	16	6	0	0	0	3	0	0	0	0
1	17	7	0	0	1	11	0	0	0	0
1	18	5	0	0	0	10	0	0	0	0
1	19	10	0	0	1	1	0	0	0	0
1	20	8	0	0	2	18	0	2	0	0
		Totals	0	0	27	167	1	14	0	14

September 03, 2005

Block	Plot	TRMT	An ge	El ca	So nu	Sc sc	Bo cu	Pa vi	Ru hi	As tu	Si la	Zi au	Ra pi	Py vi	As na	Tr oh	He he	Ec pa	Co pa	Da pu
2	21	8	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2	22	6	1	3	0	0	9	0	0	0	0	0	1	0	0	0	0	0	0	0
2	23	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
2	24	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	25	4	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
2	26	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	27	9	0	0	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0	0
2	28	3	2	0	0	0	5	0	1	0	0	0	0	0	0	0	0	1	0	0
2	29	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
2	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	31	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	32	9	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0
2	33	8	0	0	0	0	7	1	0	0	0	0	0	0	0	0	1	0	0	1
2	34	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	35	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	36	10	0	0	0	0	19	0	0	0	0	0	1	0	0	0	0	0	0	0
2	37	5	0	0	0	0	1	0	2	0	0	0	3	0	0	0	0	0	0	0
2	38	2	2	0	0	0	3	0	0	0	0	0	0	0	0	0	1	1	0	0
2	39	10	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	1	0	0
2	40	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Totals	5	3	0	0	98	1	7	0	0	0	5	0	0	0	4	3	0	1

September 03, 2005

Block	Plot	TRMT	Er yu	Li as	Le ca	De ca	So ri	An cy	Ba la	Mo fi
2	21	8	0	0	4	2	0	1	0	4
2	22	6	0	0	5	4	0	0	0	0
2	23	7	0	0	0	0	0	0	0	0
2	24	3	0	0	0	0	0	0	0	0
2	25	4	0	0	4	1	0	0	0	0
2	26	1	0	0	3	2	0	0	0	0
2	27	9	0	0	0	0	0	0	0	0
2	28	3	0	0	1	1	0	0	0	0
2	29	4	0	0	0	0	0	0	0	0
2	30	1	0	0	0	1	0	0	0	0
2	31	7	0	0	0	0	0	0	0	0
2	32	9	0	0	0	0	0	0	0	0
2	33	8	0	0	4	1	0	0	0	0
2	34	6	0	0	2	1	0	0	0	1
2	35	2	0	0	0	0	0	0	0	0
2	36	10	0	0	2	0	0	0	0	0
2	37	5	0	0	1	0	0	0	0	0
2	38	2	0	0	0	0	0	0	0	0
2	39	10	0	0	1	1	0	0	0	0
2	40	5	0	0	4	1	0	0	0	1
		Totals	0	0	31	15	0	1	0	6

August 15, 2006

Block	Plot	TRMT	**An ge**	**El ca**	**So nu**	**Sc sc**	**Bo cu**	**Pa vi**	**Ru hi**	**As tu**	**Si la**	**Zi au**	**Ra pi**	**Py vi**	**As na**	**Tr oh**	**He he**	**Ec pa**	**Co pa**	**Da pu**
1	1	1	1	22	0	0	0	0	0	0	0	4	6	0	0	0	5	1	0	1
1	2	3	0	0	0	0	1	0	1	1	0	4	5	0	0	0	4	1	0	0
1	3	4	0	29	0	0	1	0	1	1	0	5	4	0	0	0	8	0	0	0
1	4	1	0	21	0	0	0	1	2	2	3	6	4	0	0	0	6	1	0	0
1	5	2	4	0	0	1	0	0	2	0	2	2	1	0	0	0	12	3	1	0
1	6	5	1	2	0	0	8	0	1	1	0	0	1	0	0	0	7	1	0	0
1	7	2	0	7	0	0	0	0	3	2	1	1	3	0	0	1	7	1	0	0
1	8	9	0	1	0	0	57	0	1	0	0	2	0	0	0	0	3	1	0	0
1	9	7	0	2	1	0	34	0	0	0	1	1	4	0	0	0	3	2	0	1
1	10	10	0	9	0	1	9	0	0	0	0	5	0	0	0	0	4	1	0	0
1	11	8	1	6	0	0	24	1	2	0	0	10	2	0	0	0	8	1	0	0
1	12	9	0	4	0	0	43	0	0	1	0	2	4	0	0	0	11	6	0	0
1	13	3	2	0	0	0	11	0	2	1	0	3	4	0	0	0	4	2	0	0
1	14	4	1	8	1	0	2	0	1	0	0	3	0	0	0	0	4	0	0	0
1	15	6	1	8	0	0	2	0	4	0	1	4	2	0	0	0	3	3	0	0
1	16	6	0	3	0	0	5	0	0	0	0	5	0	0	0	0	3	2	0	0
1	17	7	1	2	0	0	43	0	0	0	1	4	0	0	0	0	9	2	0	0
1	18	5	2	3	0	0	16	0	1	1	1	3	2	0	0	0	2	2	0	0
1	19	10	0	8	0	2	30	0	0	0	0	6	0	0	0	0	5	2	0	0
1	20	8	2	16	0	3	22	0	0	0	0	4	5	1	0	0	2	1	0	0
		Totals	16	151	2	7	308	2	21	10	10	74	47	1	0	1	110	33	1	2

August 15, 2006

Block	Plot	TRMT	Er yu	Li as	Le ca	De ca	So ri	An cy	Ba la	Mo fi
1	1	1	0	0	1	6	1	4	0	2
1	2	3	0	0	0	8	0	2	2	3
1	3	4	0	0	0	10	0	5	1	6
1	4	1	0	0	0	4	2	4	0	3
1	5	2	0	0	0	8	1	6	1	1
1	6	5	0	0	0	5	0	2	2	5
1	7	2	0	0	0	7	0	1	0	1
1	8	9	0	0	0	5	0	2	1	6
1	9	7	0	0	0	7	0	3	4	9
1	10	10	0	0	0	2	0	3	1	2
1	11	8	0	0	0	2	2	4	1	5
1	12	9	0	0	1	2	1	1	1	0
1	13	3	0	0	0	5	0	0	0	4
1	14	4	0	0	0	4	1	1	0	1
1	15	6	0	0	0	10	1	5	1	4
1	16	6	0	0	0	1	1	6	2	1
1	17	7	0	0	1	10	0	2	0	2
1	18	5	0	0	1	9	0	2	1	2
1	19	10	0	0	0	4	1	3	0	1
1	20	8	0	0	0	7	1	2	0	1
		Totals	0	0	4	116	12	58	18	59

August 15, 2006

Block	Plot	TRMT	An ge	El ca	So nu	Sc sc	Bo cu	Pa vi	Ru hi	As tu	Si la	Zi au	Ra pi	Py vi	As na	Tr oh	He he	Ec pa	Co pa	Da pu
2	21	8	0	28	0	0	0	0	0	0	0	1	1	0	0	0	3	2	0	0
2	22	6	1	13	0	0	0	0	2	0	0	2	0	0	0	0	4	0	0	1
2	23	7	0	5	0	1	13	0	1	0	1	1	1	0	0	0	3	0	0	0
2	24	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
2	25	4	1	60	0	0	3	0	0	0	0	0	3	0	0	0	2	0	0	0
2	26	1	1	2	0	0	0	0	0	0	0	1	0	0	0	0	5	1	0	0
2	27	9	1	1	0	0	14	0	1	0	0	2	2	0	0	0	1	0	0	0
2	28	3	0	2	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
2	29	4	0	5	0	0	1	0	0	0	1	0	1	0	0	0	2	0	0	0
2	30	1	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
2	31	7	1	1	0	0	8	0	0	0	0	2	0	0	0	0	1	1	0	0
2	32	9	0	1	0	1	17	0	4	0	0	0	2	0	0	0	5	1	0	0
2	33	8	7	0	0	0	8	0	0	0	0	5	2	1	0	0	7	1	0	0
2	34	6	2	6	0	1	1	0	1	0	1	1	0	0	0	0	4	0	0	0
2	35	2	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0
2	36	10	0	9	0	0	8	0	1	0	0	6	1	0	0	0	8	1	0	0
2	37	5	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0	0	0
2	38	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4	1	0	0
2	39	10	1	5	0	1	14	0	2	0	0	3	1	0	0	0	3	0	0	0
2	40	5	0	3	0	0	5	0	0	0	0	2	0	0	0	0	3	0	0	0
		Totals	15	151	0	4	93	0	14	1	3	30	20	1	0	0	60	8	0	1

August 15, 2006

Block	Plot	TRMT	Er yu	Li as	Le ca	De ca	So ri	An cy	Ba la	Mo fi
2	21	8	0	0	0	6	0	11	0	9
2	22	6	0	0	0	3	0	2	0	7
2	23	7	0	0	0	7	2	4	0	1
2	24	3	0	0	1	0	0	0	0	2
2	25	4	0	0	0	3	0	1	0	2
2	26	1	0	0	0	3	0	6	0	2
2	27	9	0	0	0	4	0	4	0	2
2	28	3	0	0	0	0	0	2	0	3
2	29	4	0	0	0	4	0	2	0	0
2	30	1	0	0	0	0	0	2	0	0
2	31	7	0	0	0	5	0	4	0	0
2	32	9	0	0	0	3	0	6	2	1
2	33	8	0	0	0	2	0	9	0	1
2	34	6	0	0	1	2	1	9	0	3
2	35	2	0	0	0	1	1	3	0	2
2	36	10	0	0	0	4	0	4	0	2
2	37	5	0	0	0	1	0	1	1	2
2	38	2	0	0	0	3	0	3	1	1
2	39	10	0	0	0	6	0	2	1	3
2	40	5	0	0	0	2	2	3	0	1
			0	0	2	59	6	78	5	44

APPENDIX 3

WEED COUNT RAW DATA

September 03, 2005

Block	Mow	Seeding Rate	Green Amaranth	Foxtail	Barnyard grass	Prostrate Spurge	Dandelion	Buttonweed	Giant ragweed	Smartweed
1	1	1	15	2	0	0	0	2	0	0
1	2	2	14	4	0	0	0	2	0	0
1	1	2	14	2	0	0	0	10	0	0
1	1	1	15	0	1	0	0	2	0	0
1	2	1	15	6	0	0	0	0	0	0
1	2	3	15	2	0	0	0	1	0	0
1	2	1	15	3	0	1	0	8	0	0
1	2	5	15	2	0	0	0	0	0	0
1	2	4	15	1	1	0	0	1	0	0
1	1	5	15	2	0	0	1	2	0	0
1	1	4	14	6	0	0	0	0	1	0
1	2	5	12	7	0	0	0	5	0	0
1	2	2	15	4	0	0	0	1	0	0
1	1	2	12	0	0	0	0	0	0	0
1	1	3	15	3	0	0	0	2	0	2
1	1	3	11	5	0	0	0	3	0	0
1	2	4	13	6	2	0	0	0	0	0
1	2	3	15	3	4	0	0	2	0	0
1	1	5	15	2	0	0	0	3	0	0
1	1	4	15	1	0	0	0	1	0	0

September 03, 2005

Block	Mow	Seeding Rate	Panicum capillare	Indian hemp	Soybean	Siberian Elm	Carex sp	Carpetweed	Purselane
1	1	1	0	0	0	0	0	0	0
1	2	2	0	0	0	0	0	0	0
1	1	2	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	2	1	0	0	0	0	0	0	0
1	2	3	0	0	0	0	0	0	0
1	2	1	0	0	0	0	0	0	0
1	2	5	0	0	0	0	0	0	0
1	2	4	0	0	0	0	0	0	0
1	1	5	0	0	0	0	0	0	0
1	1	4	0	0	0	0	0	0	0
1	2	5	0	0	0	0	0	0	0
1	2	2	0	0	0	0	0	0	0
1	1	2	0	0	0	0	0	0	0
1	1	3	0	0	0	0	0	0	0
1	1	3	0	0	0	0	0	0	0
1	2	4	0	0	0	0	0	0	0
1	2	3	0	0	0	0	0	0	0
1	1	5	0	0	0	0	0	0	0
1	1	4	0	0	0	0	0	0	0

September 03, 2005

Block	Mow	Seeding Rate	Green Amaranth	Foxtail	Barnyard grass	Prostrate Spurge	Dandelion	Buttonweed	Giant ragweed	Smartweed
2	1	4	14	15	0	0	0	5	0	2
2	1	3	15	12	0	1	0	4	0	0
2	2	4	7	15	0	0	0	1	0	0
2	2	2	11	13	0	0	0	0	0	2
2	1	2	13	13	0	0	0	3	0	0
2	1	1	14	13	0	0	0	5	0	1
2	2	5	13	12	0	0	0	2	0	0
2	2	2	12	13	1	0	0	0	0	1
2	1	2	12	15	0	0	0	0	0	3
2	1	1	12	14	0	0	0	1	0	2
2	2	4	12	11	0	2	0	3	0	1
2	2	5	14	14	0	1	0	0	0	0
2	1	4	11	15	0	0	0	4	0	2
2	1	3	14	14	1	0	0	0	0	0
2	2	1	5	14	0	1	0	1	0	1
2	1	5	12	10	0	2	0	5	0	1
2	2	3	8	14	1	1	1	3	0	0
2	2	1	13	13	0	3	0	3	0	1
2	1	5	11	9	2	3	0	3	0	6
2	1	3	9	13	4	2	0	0	0	0

September 03, 2005

Block	Mow	Seeding Rate	Panicum capillare	Indian hemp	Soybean	Siberian Elm	Carex sp.	Carpetweed	Purselane
2	1	4	1	0	0	0	0	0	0
2	1	3	0	0	0	0	0	0	0
2	2	4	0	1	1	0	0	0	0
2	2	2	0	0	0	0	0	0	0
2	1	2	0	1	2	0	0	0	0
2	1	1	0	1	0	1	1	0	0
2	2	5	0	1	0	0	2	0	0
2	2	2	0	0	2	0	0	0	0
2	1	2	0	0	2	0	0	0	0
2	1	1	0	0	1	0	0	0	0
2	2	4	0	0	0	0	1	0	0
2	2	5	0	0	0	0	0	1	0
2	1	4	0	1	3	0	0	0	0
2	1	3	0	0	0	0	0	0	0
2	2	1	0	0	2	0	0	0	0
2	1	5	0	0	0	0	9	0	0
2	2	3	0	5	0	0	0	0	2
2	2	1	0	0	5	0	0	0	0
2	1	5	0	0	1	0	0	0	1
2	1	3	0	0	1	0	0	0	0

August 15, 2006

Block	Mow	Seeding Rate	Foxtail	Dandelion	Marestail	Fieldthistle	Sweetclover	V. groundcherry	Frost Aster	Barnyard Grass	Partridge pea	Aster sp.
1	1	1	15	1	2	2	0	0	0	0	0	0
1	2	2	15	1	3	0	1	0	0	0	0	0
1	1	2	13	0	1	0	0	1	0	0	0	0
1	1	1	15	0	0	0	0	0	0	0	0	0
1	2	1	15	0	0	0	0	0	1	0	0	0
1	2	3	15	0	2	0	0	0	0	0	0	0
1	2	1	15	0	3	0	0	0	0	1	1	1
1	2	5	13	0	1	0	0	0	0	0	0	0
1	2	4	10	2	2	0	0	0	0	0	0	0
1	1	5	15	1	0	0	0	1	0	0	0	0
1	1	4	15	0	1	0	0	0	0	0	0	0
1	2	5	15	1	3	0	0	0	0	0	0	0
1	2	2	15	0	0	0	0	0	0	0	0	0
1	1	2	11	0	0	0	0	1	0	0	0	0
1	1	3	15	0	0	0	0	0	0	0	0	0
1	1	3	14	1	3	0	0	0	0	0	0	0
1	2	4	15	0	0	0	0	0	0	1	0	0
1	2	3	14	0	0	0	0	0	0	0	0	0
1	1	5	14	0	0	0	0	0	0	0	0	0
1	1	4	13	0	0	0	0	0	0	0	0	0

August 15, 2006

Block	Mow	Seeding Rate	Sow thistle	Amaranth	Sheapards purse	Giant ragweed	Lambs-quarters	Fescue	Smartweed	Horseweed	Siberian Elm	Buttonweed
1	1	1	0	0	0	0	0	0	0	0	0	0
1	2	2	0	0	0	0	0	0	0	0	0	0
1	1	2	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0
1	2	1	0	0	0	0	0	0	0	0	0	0
1	2	3	0	0	0	0	0	0	0	0	0	0
1	2	1	0	0	0	0	0	0	0	0	0	0
1	2	5	2	0	0	0	0	0	0	0	0	0
1	2	4	0	3	0	0	0	0	0	0	0	0
1	1	5	0	0	3	0	0	0	0	0	0	0
1	1	4	0	0	0	1	1	0	0	0	0	0
1	2	5	0	0	0	0	0	0	0	0	0	0
1	2	2	0	0	0	0	0	1	1	1	0	0
1	1	2	0	0	0	0	0	0	1	0	0	0
1	1	3	0	0	0	0	0	0	0	0	0	0
1	1	3	1	1	0	0	0	0	0	0	0	0
1	2	4	0	0	0	0	0	0	0	0	0	0
1	2	3	0	0	0	0	0	0	0	0	0	0
1	1	5	0	0	0	0	0	0	0	0	0	0
1	1	4	0	0	0	0	0	0	0	0	0	0

August 15, 2006

Block	Mow	Seeding Rate	Foxtail	Dandelion	Marestail	Fieldthistle	Sweetclover	V. groundcherry	Frost Aster	Barnyard Grass	Partridge pea	Aster sp.
2	1	4	15	0	0	0	0	0	0	0	0	0
2	1	3	15	0	0	0	0	0	0	0	0	0
2	2	4	15	0	0	0	1	0	0	0	1	0
2	2	2	15	0	0	0	0	0	1	0	0	0
2	1	2	15	0	0	0	0	0	0	0	1	0
2	1	1	15	0	3	0	0	0	0	0	0	0
2	2	5	15	1	0	0	0	0	0	0	0	0
2	2	2	15	0	0	0	0	0	0	0	0	0
2	1	2	15	0	1	0	0	0	0	0	0	0
2	1	1	15	0	2	0	0	0	0	0	0	0
2	2	4	15	0	0	0	0	0	0	0	0	0
2	2	5	15	1	0	0	0	0	0	0	0	0
2	1	4	15	0	0	0	0	0	0	0	0	0
2	1	3	15	0	0	0	0	0	0	0	0	0
2	2	1	15	0	0	0	0	0	0	0	0	0
2	1	5	15	0	0	0	0	0	0	0	0	0
2	2	3	15	0	0	0	0	0	0	0	0	0
2	2	1	15	0	0	0	0	0	0	0	0	0
2	1	5	15	0	0	0	0	0	0	0	0	0
2	1	3	15	0	0	0	0	0	0	0	0	0

August 15, 2006

Block	Mow	Seeding Rate	Sow thistle	Amaranth	Sheapards purse	Giant ragweed	Lambs-quarters	Fescue	Smartweed	Horseweed	Siberian Elm	Buttonweed
2	1	4	0	0	0	0	0	0	0	0	0	0
2	1	3	0	0	0	0	1	0	1	0	1	0
2	2	4	0	0	0	0	0	0	0	0	0	0
2	2	2	0	0	0	0	0	0	3	0	0	0
2	1	2	0	0	0	0	0	0	3	0	0	0
2	1	1	0	0	0	0	0	0	0	0	0	0
2	2	5	0	0	0	0	0	0	0	0	0	0
2	2	2	0	0	0	0	0	0	2	0	0	0
2	1	2	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	2	0	0	1
2	2	4	0	0	0	0	0	0	0	0	0	0
2	2	5	0	0	0	0	0	0	0	0	0	0
2	1	4	0	0	0	0	0	0	0	0	0	0
2	1	3	0	0	0	0	0	0	0	0	0	0
2	2	1	0	0	0	0	0	0	1	0	0	0
2	1	5	0	0	0	0	0	0	0	1	0	0
2	2	3	0	0	0	0	0	0	0	1	0	0
2	2	1	0	0	0	0	0	0	0	0	0	0
2	1	5	0	0	0	0	0	0	0	2	0	0
2	1	3	0	0	0	0	0	0	2	1	0	0

APPENDIX 4

LIGHT MEASUREMENT RAW DATA

3-Sep-05 Block	Plot	Treatment	Reading 1	Light Data Reading 2	Reading 3	Reading 4	Reading 5	Avg.
1	1	1	58	57	75	78	79	69.40
1	2	3	114	117	119	118	120	117.60
1	3	4	62	64	62	105	46	67.80
1	4	1	38	77	78	86	97	75.20
1	5	2	1213	1214	1202	1210	1207	1209.20
1	6	5	615	606	325	439	500	497.00
1	7	2	1363	1373	1376	1380	1400	1378.40
1	8	9	309	304	303	305	296	303.40
1	9	7	1334	1307	1306	1311	1318	1315.20
1	10	10	45	64	62	93	71	67.00
1	11	8	31	32	30	33	31	31.40
1	12	9	1525	1521	1526	1527	1560	1531.80
1	13	3	182	181	176	177	190	181.20
1	14	4	69	70	71	69	69	69.60
1	15	6	55	54	55	54	55	54.60
1	16	6	25	25	25	31	30	27.20
1	17	7	411	455	753	367	320	461.20
1	18	5	118	119	118	120	118	118.60
1	19	10	31	32	33	66	60	44.40
1	20	8	62	79	71	38	58	61.60
2	21	8	85.89	193	105	89	107	115.98
2	22	6	81.7	80.2	80.1	80.3	80.4	80.54
2	23	7	1377	1276	1297	1304	700	1190.80
2	24	3	1600	1601	1603	1602	1603	1601.80
2	25	4	59.8	59.9	60.1	60	60.3	60.02
2	26	1	1208	1224	1193	1210	1110	1189.00
2	27	9	1430	1427	1429	1431	1433	1430.00
2	28	3	1206	1200	1158	1198	1178	1188.00
2	29	4	48	51	48.6	46	47	48.12
2	30	1	13.77	33	25	26	30	25.55
2	31	7	1314	1313	1311	1312	1314.8	1312.96
2	32	9	1642	1643	1643.2	1649	1646	1644.64
2	33	8	1451	1447	1454	1459	1408	1443.80
2	34	6	38	54	32	45	40	41.80
2	35	2	1412	1422	1423	1421	1427	1421.00
2	36	10	971	908	720	775	605	795.80
2	37	5	1586	1586.7	1589	1588	1587	1587.34
2	38	2	283	214	1700	518	484	639.80
2	39	10	170	298	200	120	256	208.80
2	40	5	1422	1417	1414	1421	1417	1418.20

15-Aug-06 Block	Plot	Treatment	Reading 1	Light Data Reading 2	Reading 3	Reading 4	Reading 5	Avg.
1	1	1	71	71	72	71	73	71.60
1	2	3	195	187	187	190	187	189.20
1	3	4	216	191	182	293	125	201.40
1	4	1	311	333	334	340	332	330.00
1	5	2	567	1068	1134	1137	924.5	966.10
1	6	5	111	105	103	106	105	106.00
1	7	2	94	94	93	92	93	93.20
1	8	9	163	163	185	231	167	181.80
1	9	7	123.2	235.1	700.4	620.8	980.3	531.96
1	10	10	67	75	82	76	82	76.40
1	11	8	154	153	153	154	154	153.60
1	12	9	426	437	475	531	519	477.60
1	13	3	664	982	1246	1157	1460	1101.80
1	14	4	585	569	531	573	685	588.60
1	15	6	105	106	104	105	103	104.60
1	16	6	107	104	104	103	105	104.60
1	17	7	865	1876	554	464	873	926.40
1	18	5	319	958	386	301	333	459.40
1	19	10	93	94	91	92	93	92.60
1	20	8	115	119	118	124	185	132.20
2	21	8	322	322	343	349	526	372.40
2	22	6	221	407	384	362	344	343.60
2	23	7	1754	542	803	2212	1247	1311.60
2	24	3	888	735	722	708	706	751.80
2	25	4	82	83	91	81	84	84.20
2	26	1	268	261	258	264	267	263.60
2	27	9	847	1404	1711	982	1055	1199.80
2	28	3	71	107	110	106	106	100.00
2	29	4	47	70	70	70	74	66.20
2	30	1	43	43	42	42	41	42.20
2	31	7	280.1	279	494	307	247	321.42
2	32	9	588	916	1196	904	889	898.60
2	33	8	178	260	269	288	301	259.20
2	34	6	22	25	24	25	22	23.60
2	35	2	179	300	266	275	340	272.00
2	36	10	232	337.5	329.8	464	494	371.46
2	37	5	420.5	385.6	379.4	410.4	720	463.18
2	38	2	311	322	298	301	282	302.80
2	39	10	1755	1596	2551	2621	2323	2169.20
2	40	5	1385	1496	1379	1988	2334	1716.40

APPENDIX 5

BIOMASS RAW DATA NATIVES AND WEEDS

September 03, 2005

Block	Seeding Rate	Mowing	Weeds (g)	Grass (g)	Forb (g)	Side oats (g)	Natives
1	1	1	95.642	0.012	0.318	0	0.165
1	1	1	82.71	0.008	0.04	0	0.024
1	1	2	5.824	0.02	0.006	0	0.013
1	1	2	19.898	0	0.034	0	0.017
1	2	1	62.018	0.002	0.555	0.192	0.247778
1	2	1	67.272	0.06	0.038	0.08	0.049
1	2	2	11.678	0	0.2825	0.062	0.125556
1	2	2	15.84	0	0.224	0.128	0.112
1	3	1	62.628	0	0.006	0.142	0.003
1	3	1	73.525	0.008	0.002	0.062	0.005
1	3	2	17.794	0.002	0.058	0.032	0.03
1	3	2	13.392	0.084	0.754	0.848	0.419
1	4	1	65.976	0.142	0.006	0.916	0.074
1	4	1	52.728	0.06	0.684	1.372	0.372
1	4	2	11.158	0	0.052	0.388	0.026
1	4	2	15.61	0	0.68	0.818	0.34
1	5	1	74.904	0.022	0.06	0.088	0.041
1	5	1	69.83	0	0	0.094	0
1	5	2	6.076	0.438	0.182	0.5	0.31
1	5	2	14.3312	0.2895	0.3604	2.602	0.314
2	1	1	65.608	0	0.072	0.08	0.036
2	1	1	61.29	0	0.062	0	0.031
2	1	2	9.774	0	0	0	0
2	1	2	15.3688	0.01	0	0.016	0.005
2	2	1	50.236	0	0.044	0.11	0.022
2	2	1	63.14	0	0	0	0
2	2	2	13.308	0	0	0	0
2	2	2	16.762	0	0	0.018	0
2	3	1	55.724	0	0.02	0.046	0.008889
2	3	1	60.642	0	0.106	0	0.053
2	3	2	21.458	0	0.014	0.002	0.007
2	3	2	14.526	0	0.008	0	0.004
2	4	1	54.56	0	0.004	0.002	0.002
2	4	1	34.638	0.05	0	0.004	0.025
2	4	2	15.184	0	0	0.002	0
2	4	2	7.9	0	0	0.05	0
2	5	1	53.366	0	0.002	0.008	0.001
2	5	1	41.0192	0	0.0004	0.1656	0.0002
2	5	2	8.982	0	0	0.006	0
2	5	2	19.788	0	0	0.052	0

August 15, 2006

Block	Mow	Seeding rate	weeds	grass	forbs	sideoats	Natives
1	1	1	57.76	12.54	0.78	0	13.32
1	1	1	19.98	20.68	1.4	0	22.08
1	2	1	26.1	0.82	2.6	0	3.42
1	2	1	38.6	0	2.52	0	2.52
1	1	2	10.375	50.32	3.18	1.4	53.5
1	1	2	12.02	50.26	6.5	0.46	56.76
1	2	2	38.3	1.66	2.22	0	3.88
1	2	2	32.28	0.08	1.86	3.78	1.94
1	1	3	8.42	13.12	19.6	0.42	32.72
1	1	3	92.3	2.1	0.16	1.46	2.26
1	2	3	36.94	0.52	1.46	3.16	1.98
1	2	3	36	3.06	3.2	8.02	6.26
1	1	4	29.52	19.16	1.66	1.3	20.82
1	1	4	11.68	65.425	0.42	14.44	65.845
1	2	4	24.3	0.64	0.22	3.94	0.86
1	2	4	26.68	1.36	1.5	13.84	2.86
1	1	5	27.84	5.02	1.68	0.3	6.7
1	1	5	19	17.54	1.68	5.92	19.22
1	2	5	18.46	0	0.36	11.88	0.36
1	2	5	32.94	5.04	0.78	10.62	5.82
2	1	1	49.26	0.54	0.08	0	0.62
2	1	1	73.9	0	0.02	0	0.02
2	2	1	41.12	0	1.28	0	1.28
2	2	1	45.48	0	0.62	0	0.62
2	1	2	32.06	8.34	0.16	0.12	8.5
2	1	2	60.78	7.96	0.14	0	8.1
2	2	2	22.8	0.02	2.48	0	2.5
2	2	2	30.1	0	0.02	1.38	0.02
2	1	3	22.3	12.88	1.72	0	14.6
2	1	3	57.36	1.52	0.5	0	2.02
2	2	3	42.82	0	1.2	0	1.2
2	2	3	46.96	0	0.4	0.06	0.4
2	1	4	17.58	4.56	1.7	0	6.26
2	1	4	30.6	9.72	2.24	1.98	11.96
2	2	4	29.26	0.36	0.24	1.26	0.6
2	2	4	38.72	1.92	0.8	0.52	2.72
2	1	5	20.32	14.52	1.42	0.18	15.94
2	1	5	33.424	11.684	0.624	1.376	12.308
2	2	5	37.48	0	0.08	1.02	0.08
2	2	5	27.88	0.58	1.1	2.54	1.68

APPENDIX 6

B.curtipendula ROOT AND SHOOT BIOMASS DATA

August 15, 2006

Block	Plot #	Seeding rate	Mowing	Rbiom (g)	Sbioma(g)
1	14	2	1	1.3	0.8
1	3	2	1	1.8	0.2
1	2	2	2	6	0.5
1	13	2	2	1.5	1.2
1	15	3	1	1.3	0.3
1	16	3	1	2.5	1.8
1	6	3	2	1.3	0.3
1	18	3	2	3.6	0.9
1	20	4	1	3.2	0.7
1	11	4	1	3.8	0.2
1	9	4	2	5.8	0.9
1	17	4	2	1.7	0.8
1	19	5	1	1.6	0.2
1	10	5	1	1	0.5
1	8	5	2	5.9	0.8
1	12	5	2	3.9	0.5
2	25	2	1	0.2	0
2	29	2	1	2	0.9
2	28	2	2	4.2	1.8
2	24	2	2	1.1	1.5
2	34	3	1	1.4	0.1
2	22	3	1	0.9	0.7
2	40	3	2	0.6	0.8
2	37	3	2	4.8	1.2
2	21	4	1	6.1	0.3
2	33	4	1	6.7	2
2	31	4	2	1	0.8
2	23	4	2	3.4	0.6
2	36	5	1	4.6	0.6
2	39	5	1	4.3	0.6
2	27	5	2	1.1	0.6
2	32	5	2	0.8	0.2

APPENDIX 7

ANOVA TABLES

Table 1: Effects of experimental treatments on the surface light collected in September of 2005. A 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	1071.310	1	1071.310	15.043	0.001
SDRT	494.469	4	123.617	1.736	0.182
MOW	3463.481	1	3463.481	48.634	0.000
BLOCK*SDRT	120.940	4	30.235	0.425	0.789
BLOCK*MOW	28.566	1	28.566	0.401	0.534
SDRT*MOW	25.740	4	6.435	0.090	0.984
BLOCK*SDRT*MOW	715.851	4	178.963	2.513	0.074
Error	1424.315	20	71.216		

Table 2: Effects of experimental treatments on the surface light collected in August of 2006. A 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	166.727	1	166.727	1.974	0.175
SDRT	294.576	4	73.644	0.872	0.498
MOW	712.343	1	712.343	8.435	0.009
BLOCK*SDRT	866.137	4	216.534	2.564	0.070
BLOCK*MOW	1.551	1	1.551	0.018	0.894
SDRT*MOW	115.982	4	28.996	0.343	0.845
BLOCK*SDRT*MOW	172.558	4	43.140	0.511	0.728
Error	1689.009	20	84.450		

Table 3: Effects of experimental treatments on the number of total native plants counted in September of 2005 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	77.243	1	77.243	59.076	0.000
MOW	4.968	1	4.968	3.799	0.065
SDRT	3.381	4	0.845	0.646	0.636
BLOCK*MOW	0.379	1	0.379	0.290	0.596
BLOCK*SDRT	8.783	4	2.196	1.679	0.194
MOW*SDRT	4.341	4	1.085	0.830	0.522
BLOCK*MOW*SDRT	6.554	4	1.638	1.253	0.321
Error	26.150	20	1.308		

Table 4: Effects of experimental treatments on the number of total native seedlings counted in August of 2006 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	16.172	1	16.172	12.755	0.002
MOW	16.208	1	16.208	12.784	0.002
SDRT	3.548	4	0.887	0.700	0.601
BLOCK*MOW	2.475	1	2.475	1.952	0.178
BLOCK*SDRT	10.881	4	2.720	2.145	0.113
MOW*SDRT	3.374	4	0.844	0.665	0.623
BLOCK*MOW*SDRT	3.420	4	0.855	0.674	0.618
Error	25.358	20	1.268		

Table 5: Effects of experimental treatments on the number of *B. curtipendula* seedlings counted in September of 2005 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	21.212	1	21.212	19.218	0.000
MOW	1.927	1	1.927	1.746	0.201
SDRT	76.704	4	19.176	17.374	0.000
BLOCK*MOW	4.450	1	4.450	4.032	0.058
BLOCK*SDRT	20.439	4	5.110	4.630	0.008
MOW*SDRT	2.193	4	0.548	0.497	0.738
BLOCK*MOW*SDRT	3.156	4	0.789	0.715	0.592
Error	22.075	20	1.104		

Table 6: Effects of experimental treatments on the number of *B. curtipendula* seedlings counted in August of 2006 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	24.190	1	24.190	29.866	0.000
MOW	8.023	1	8.023	9.905	0.005
SDRT	116.878	4	29.219	36.075	0.000
BLOCK*MOW	2.073	1	2.073	2.559	0.125
BLOCK*SDRT	12.003	4	3.001	3.705	0.021
MOW*SDRT	5.538	4	1.384	1.709	0.187
BLOCK*MOW*SDRT	2.481	4	0.620	0.766	0.560
Error	16.199	20	0.810		

Table 7: Effects of experimental treatments on the species richness of native seedlings counted in September of 2005 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	193.600	1	193.600	56.116	0.000
MOW	8.100	1	8.100	2.348	0.141
SDRT	10.150	4	2.537	0.736	0.579
BLOCK*MOW	1.600	1	1.600	0.464	0.504
BLOCK*SDRT	25.650	4	6.413	1.859	0.157
MOW*SDRT	15.150	4	3.787	1.098	0.385
BLOCK*MOW*SDRT	48.650	4	12.162	3.525	0.025
Error	69.000	20	3.450		

Table 8: Effects of experimental treatments on the species richness of native seedlings counted in August of 2006 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	112.225	1	112.225	22.333	0.000
MOW	0.225	1	0.225	0.045	0.835
SDRT	3.850	4	0.963	0.192	0.940
BLOCK*MOW	0.625	1	0.625	0.124	0.728
BLOCK*SDRT	21.650	4	5.413	1.077	0.394
MOW*SDRT	17.150	4	4.287	0.853	0.508
BLOCK*MOW*SDRT	17.750	4	4.438	0.883	0.492
Error	100.500	20	5.025		

Table 9: Effects of experimental treatments on the species richness of weed species counted in September of 2005 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	2.662	1	2.662	84.218	0.000
MOW	0.019	1	0.019	0.605	0.446
SEEDRTE	0.059	4	0.015	0.465	0.760
BLOCK*MOW	0.129	1	0.129	4.089	0.057
BLOCK*SEEDRTE	0.029	4	0.007	0.228	0.919
MOW*SEEDRTE	0.146	4	0.036	1.154	0.360
BLOCK*MOW*SEEDRTE	0.111	4	0.028	0.875	0.496
Error	0.632	20	0.032		

Table 10: Effects of experimental treatments on the species richness of weed species counted in September of 2005 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.001	1	0.001	0.078	0.783
MOW	0.001	1	0.001	0.078	0.783
SEEDRTE	0.031	4	0.008	0.792	0.544
BLOCK*MOW	0.015	1	0.015	1.584	0.223
BLOCK*SEEDRTE	0.013	4	0.003	0.320	0.861
MOW*SEEDRTE	0.046	4	0.012	1.187	0.347
BLOCK*MOW*SEEDRTE	0.025	4	0.006	0.635	0.643
Error	0.196	20	0.010		

Table 11: Effects of experimental treatments on the Simpson's Index of Dominance, seedlings counted in September of 2005 a 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.009	1	0.009	0.210	0.652
MOW	0.294	1	0.294	7.023	0.015
SDRT	0.277	4	0.069	1.654	0.200
BLOCK*MOW	0.092	1	0.092	2.189	0.155
BLOCK*SDRT	0.614	4	0.154	3.670	0.021
MOW*SDRT	0.216	4	0.054	1.293	0.306
BLOCK*MOW*SDRT	0.140	4	0.035	0.838	0.517
Error	0.837	20	0.042		

Table 12: Effects of experimental treatments on the Simpson's Index of Dominance, seedlings counted in August of 2006 a 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.000	1	0.000	0.023	0.881
MOW	0.000	1	0.000	0.013	0.911
SDRT	0.086	4	0.021	1.486	0.244
BLOCK*MOW	0.021	1	0.021	1.464	0.240
BLOCK*SDRT	0.050	4	0.012	0.863	0.503
MOW*SDRT	0.004	4	0.001	0.061	0.993
BLOCK*MOW*SDRT	0.074	4	0.018	1.283	0.310
Error	0.288	20	0.014		

Table 13: Effects of experimental treatments on the frequency of green amaranth counted in September of 2005 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	1.747	1	1.747	15.769	0.001
MOW	0.223	1	0.223	2.011	0.172
SEEDRTE	0.148	4	0.037	0.334	0.852
BLOCK*MOW	0.363	1	0.363	3.279	0.085
BLOCK*SEEDRTE	0.238	4	0.060	0.538	0.709
MOW*SEEDRTE	0.246	4	0.062	0.556	0.697
BLOCK*MOW*SEEDRTE	0.581	4	0.145	1.311	0.300
Error	2.215	20	0.111		

Table 14: Effects of experimental treatments on the frequency of foxtail counted in September of 2005 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	39.618	1	39.618	141.659	0.000
MOW	0.948	1	0.948	3.388	0.081
SEEDRTE	0.372	4	0.093	0.332	0.853
BLOCK*MOW	0.671	1	0.671	2.400	0.137
BLOCK*SEEDRTE	0.655	4	0.164	0.586	0.677
MOW*SEEDRTE	1.313	4	0.328	1.174	0.352
BLOCK*MOW*SEEDRTE	1.390	4	0.347	1.242	0.325
Error	5.594	20	0.280		

Table 15: Effects of experimental treatments on the frequency of buttonweed counted in September of 2005 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.011	1	0.011	0.011	0.917
MOW	1.039	1	1.039	1.072	0.313
SEEDRTE	1.428	4	0.357	0.368	0.828
BLOCK*MOW	0.076	1	0.076	0.078	0.782
BLOCK*SEEDRTE	4.992	4	1.248	1.287	0.308
MOW*SEEDRTE	1.619	4	0.405	0.417	0.794
BLOCK*MOW*SEEDRTE	1.529	4	0.382	0.394	0.810
Error	19.394	20	0.970		

Table 16: Effects of experimental treatments on the frequency of smartweed counted in September of 2005 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	5.034	1	5.034	23.844	0.000
MOW	0.998	1	0.998	4.730	0.042
SEEDRTE	0.637	4	0.159	0.754	0.567
BLOCK*MOW	0.313	1	0.313	1.482	0.238
BLOCK*SEEDRTE	2.613	4	0.653	3.094	0.039
MOW*SEEDRTE	1.203	4	0.301	1.424	0.262
BLOCK*MOW*SEEDRTE	1.828	4	0.457	2.165	0.110
Error	4.222	20	0.211		

Table 17: Effects of experimental treatments on the frequency of foxtail counted in August of 2006 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.147	1	0.147	7.496	0.013
MOW	0.001	1	0.001	0.074	0.789
SEEDRTE	0.080	4	0.020	1.024	0.419
BLOCK*MOW	0.001	1	0.001	0.074	0.789
BLOCK*SEEDRTE	0.080	4	0.020	1.024	0.419
MOW*SEEDRTE	0.110	4	0.028	1.406	0.268
BLOCK*MOW*SEEDRTE	0.110	4	0.028	1.406	0.268
Error	0.392	20	0.020		

Table 18: Effects of experimental treatments on the frequency of marestail counted in August of 2006 using a 3-way ANOVA.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	2.431	1	2.431	5.218	0.033
MOW	0.002	1	0.002	0.004	0.952
SEEDRTE	1.197	4	0.299	0.642	0.639
BLOCK*MOW	1.558	1	1.558	3.344	0.082
BLOCK*SEEDRTE	0.738	4	0.184	0.396	0.809
MOW*SEEDRTE	1.973	4	0.493	1.059	0.403
BLOCK*MOW*SEEDRTE	1.164	4	0.291	0.625	0.650
Error	9.318	20	0.466		

Table 19: Effects of experimental treatments on the frequency of smartweed counted in August of 2006 using a 3-way ANOVA.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	1.153	1	1.153	4.513	0.046
MOW	0.009	1	0.009	0.035	0.853
SEEDRTE	3.989	4	0.997	3.905	0.017
BLOCK*MOW	0.009	1	0.009	0.035	0.853
BLOCK*SEEDRTE	0.896	4	0.224	0.877	0.495
MOW*SEEDRTE	0.545	4	0.136	0.534	0.712
BLOCK*MOW*SEEDRTE	0.545	4	0.136	0.534	0.712
Error	5.108	20	0.255		

Table 20: Effects of experimental treatments on the total native plant biomass, except *B. curtipendula* collected in September of 2005. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.576	1	0.576	30.420	0.000
SDRT	0.025	4	0.006	0.332	0.853
MOW	0.002	1	0.002	0.086	0.772
BLOCK*SDRT	0.124	4	0.031	1.630	0.206
BLOCK*MOW	0.099	1	0.099	5.252	0.033
SDRT*MOW	0.191	4	0.048	2.527	0.073
BLOCK*SDRT*MOW	0.113	4	0.028	1.496	0.241
Error	0.379	20	0.019		

Table 21: Effects of experimental treatments on the total native plant biomass, except *B. curtipendula* collected in August of 2006. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	25.034	1	25.034	19.344	0.000
MOW	61.883	1	61.883	47.819	0.000
SDRT	9.872	4	2.468	1.907	0.149
BLOCK*MOW	7.840	1	7.840	6.058	0.023
BLOCK*SDRT	7.575	4	1.894	1.463	0.251
MOW*SDRT	11.306	4	2.827	2.184	0.108
BLOCK*MOW*SDRT	9.249	4	2.312	1.787	0.171
Error	25.882	20	1.294		

Table 22: Effects of experimental treatments on the total native grass biomass, except *B. curtipendula* collected in September of 2005. A 3-way ANOVA was used for data anaylsis

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.182	1	0.182	29.975	0.000
SDRT	0.094	4	0.023	3.846	0.018
MOW	0.001	1	0.001	0.171	0.684
BLOCK*SDRT	0.105	4	0.026	4.312	0.011
BLOCK*MOW	0.005	1	0.005	0.837	0.371
SDRT*MOW	0.245	4	0.061	10.060	0.000
BLOCK*SDRT*MOW	0.174	4	0.044	7.154	0.001
Error	0.122	20	0.006		

Table 23: Effects of experimental treatments on the total native grass biomass, except *B. curtipendula* collected in August of 2006. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	20.678	1	20.678	20.784	0.000
MOW	83.921	1	83.921	84.352	0.000
SDRT	14.467	4	3.617	3.635	0.022
BLOCK*MOW	6.577	1	6.577	6.611	0.018
BLOCK*SDRT	7.561	4	1.890	1.900	0.150
MOW*SDRT	9.987	4	2.497	2.510	0.074
BLOCK*MOW*SDRT	12.629	4	3.157	3.173	0.036
Error	19.898	20	0.995		

Table 24: Effects of experimental treatments on the total native forb biomass, except *B. curtipendula* collected in September of 2005. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.871	1	0.871	17.984	0.000
SDRT	0.058	4	0.015	0.301	0.874
MOW	0.003	1	0.003	0.069	0.795
BLOCK*SDRT	0.207	4	0.052	1.070	0.397
BLOCK*MOW	0.168	1	0.168	3.476	0.077
SDRT*MOW	0.261	4	0.065	1.346	0.288
BLOCK*SDRT*MOW	0.131	4	0.033	0.674	0.618
Error	0.968	20	0.048		

Table 25: Effects of experimental treatments on the total native forb biomass, except *B. curtipendula* collected in August of 2006. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCKS	3.543	1	3.543	6.433	0.020
MOW	0.297	1	0.297	0.539	0.471
SDRT	1.603	4	0.401	0.728	0.584
BLOCKS*MOW	0.325	1	0.325	0.591	0.451
BLOCKS*SDRT	2.471	4	0.618	1.122	0.374
MOW*SDRT	1.895	4	0.474	0.860	0.505
BLOCKS*MOW*SDRT	0.918	4	0.230	0.417	0.795
Error	11.016	20	0.551		

Table 26: Effects of experimental treatments on the total *B. curtipendula* biomass collected in September of 2005. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	1.340	1	1.340	27.107	0.000
SDRT	1.115	4	0.279	5.642	0.003
MOWING	0.021	1	0.021	0.430	0.520
BLOCK*SDRT	0.950	4	0.238	4.806	0.007
BLOCK*MOWING	0.103	1	0.103	2.084	0.164
SDRT*MOWING	0.321	4	0.080	1.624	0.207
BLOCK*SDRT*MOWING	0.480	4	0.120	2.429	0.081
Error	0.988	20	0.049		

Table 27: Effects of experimental treatments on the total *B. curtipendula* biomass collected in August of 2006. A 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	11.434	1	11.434	19.266	0.000
MOWING	2.422	1	2.422	4.080	0.057
SDRT	17.778	4	4.445	7.489	0.001
BLOCK*MOWING	0.578	1	0.578	0.974	0.335
BLOCK*SDRT	4.653	4	1.163	1.960	0.140
MOWING*SDRT	1.784	4	0.446	0.752	0.569
BLOCK*MOWING*SDRT	1.215	4	0.304	0.512	0.728
Error	11.869	20	0.593		

Table 28: Effects of experimental treatments on the total weed biomass collected in September of 2005. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	2.000	1	2.000	4.559	0.045
SDRT	3.178	4	0.795	1.811	0.166
MOWING	176.211	1	176.211	401.642	0.000
BLOCK*SDRT	0.541	4	0.135	0.309	0.869
BLOCK*MOWING	3.802	1	3.802	8.667	0.008
SDRT*MOWING	2.987	4	0.747	1.702	0.189
BLOCK*SDRT*MOWING	0.879	4	0.220	0.501	0.736
Error	8.775	20	0.439		

Table 29: Effects of experimental treatments on the total weed biomass collected in September of 2005. A 3-way ANOVA was used for data anaylsis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	6.462	1	6.462	3.077	0.095
MOW	0.423	1	0.423	0.201	0.658
SDRT	15.189	4	3.797	1.808	0.167
BLOCK*MOW	1.290	1	1.290	0.614	0.442
BLOCK*SDRT	1.875	4	0.469	0.223	0.922
MOW*SDRT	2.939	4	0.735	0.350	0.841
BLOCK*MOW*SDRT	8.264	4	2.066	0.984	0.439
Error	42.009	20	2.100		

Table 30: Effects of experimental treatments on the total root biomass collected in August of 2006. A 3-way ANOVA was used for data analysis.

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.114	1	0.114	0.426	0.523
SDRT	1.607	3	0.536	1.998	0.155
MOW	0.045	1	0.045	0.168	0.687
BLOCK*SDRT	0.177	3	0.059	0.220	0.881
BLOCK*MOW	1.140	1	1.140	4.252	0.056
SDRT*MOW	1.487	3	0.496	1.849	0.179
BLOCK*SDRT*MOW	1.928	3	0.643	2.396	0.106
Error	4.291	16	0.268		

Table 31: Effects of experimental treatments on the shoot biomass collected in August of 2006. A 3-way ANOVA was used for data anaylsis.
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
BLOCK	0.013	1	0.013	0.120	0.734
SDRT	0.121	3	0.040	0.370	0.776
MOW	0.264	1	0.264	2.420	0.139
BLOCK*SDRT	0.043	3	0.014	0.132	0.940
BLOCK*MOW	0.018	1	0.018	0.165	0.690
SDRT*MOW	0.311	3	0.104	0.949	0.441
BLOCK*SDRT*MOW	0.504	3	0.168	1.538	0.243
Error	1.748	16	0.109		