Establishing Native Plants on Abandoned Farmland at Rabbit Mountain Open Space, Boulder County, Colorado: Year 2

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SECTION 1 – ABSTRACT

This project addressed the priority research need to evaluate restoration techniques for former agricultural lands, particularly the establishment of diverse, stable native plant communities. This research (1) evaluated the abundance of native species planted in different proportions and compositions during the first year after seeding, (2) examined factors associated with success and failure of native plant establishment including weedy, non-native species, and soil nitrogen (N) and carbon (C) levels, and (3) established long term research plots for future research. Non-seeded species, which included native and non-native species, had much greater cover than seeded species. Slender wheatgrass and western wheatgrass were the most abundant seeded grasses, while fourwing saltbush was the most abundant broadleaf species. Generally, the representation of seeded grasses and forbs reflected the proportion seeded in the first year, but this pattern began to weaken in the second year. After two years, cover of seeded species decreased with while non-seeded species cover increased, suggesting negative competitive effects. Cover of non-seeded species was negatively correlated with soil percent C, while cover of seeded species was positively correlated with this variable. The cover of non-seeded and seeded species and their performance in different seeding mixtures were related to the location in the study area indicated by block. This work documents the development of a plant community over time. We are beginning to see important interactions between seeded and non-seeded species, and between the plants and abiotic factors. This work is providing the opportunity for long term research that will inform BCPOS and other land managers about which methods are most effective for restoration of native prairie communities and control of undesirable non-native species.

INTRODUCTION

Colorado grasslands have been heavily impacted by agriculture. Re-establishing stable, productive and invasion resistant plant communities on lands that were once farmed is a huge challenge. It is possible to restore native, perennial vegetation to disturbed areas in arid regions (Bugg *et al.* 1997), but many questions remain about which approaches are most effective. The establishment of native shrubs from seed can prove to be especially difficult and the ideal proportion of grasses, forbs and shrubs to include in seed mixtures for optimal establishment of diverse plant communities is not well known. Previous work suggests that first establishing native perennial grasses to allow control of broadleaf weeds during establishment, then introducing forbs can be a successful approach to take, although grasses may need to be mowed or burned to facilitate forb establishment (Brown and Bugg 2001). In the work proposed here, we addressed the priority research need of Boulder County Parks and Open Space (BCPOS) to evaluate restoration techniques for former agricultural lands, particularly the establishment of diverse, stable native plant communities.

In this research project, we

1. quantified the abundance of native species planted in different proportions and compositions during the first year after seeding,
2. evaluated factors associated with success and failure of native plant establishment including abundance and identity of non-native, weedy and invasive plants, soil nitrogen (N) and carbon (C), light availability, and vertebrate activity, and
3. established long-term research plots for future research.

We tested the following hypotheses: (1) Abundance of seeded grasses, herbaceous forbs and shrubs will reflect their proportions in the seed mixtures. Alternatively, the abundance of seeded species may differ from their proportional representation in the seed mixtures; (2) Success of seeded species will be positively associated with (a) low weed abundance, (b) high N levels when weeds are not present, (c) low N levels when weeds are present, and (d) reduced light availability. Alternatively, success of seeded species may be unrelated to these factors or show a different relationship than we expect.

METHODS

Study Site - The experimental plots are located in the Cemex Research Site shown in Figure 1. The site was planted with milo or grain sorghum (*Sorghum bicolor*) the year prior to initiation of the experiment.

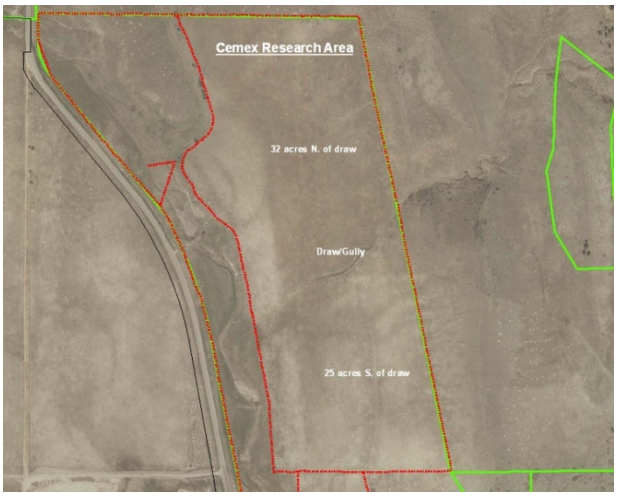


Figure 1. The CEMEX Research Site is located south of the Rabbit Mountain Open Space parking area, and east of the county road. It is outlined in red.

Experimental Design - The experiment is a complete randomized block design with four seed mixture treatments (Figure 2). Seeding rates and composition were determined by BCPOS Plant Ecologist Claire DeLeo and the mixtures were seeded February 1 - 3, 2006 by BCPOS personnel using a Truax FLX816 seed drill (10.5 ft wide with 16 rows, 8 inches apart) (Truax,

Inc., New Hope, Minnesota). Brown developed the experimental design and assisted with the first day of laying out the plots in January, 2006.

As shown in Figure 2, there are four blocks of 18 monoculture plots in addition to the mixture treatment plots. The monoculture plots are located in strips (10 ft wide, one drill width) between the mixture plots. Individual plots (10 ft x 10 ft) were seeded with a single species or cultivar that is included in the mixtures. Seed was broadcast at a rate of 50 PLS seeds/ft^2 and raked in by hand in February 2006. The species assignments to plots are detailed in Appendix 1.

Seed mixtures - The grasses included in each of the seed mixes were side oats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), slender wheatgrass (*Elymus trachycaulus*), prairie junegrass (*Koeleria macrantha*), western wheatgrass (*Pascopyrum smithii*) (1 cultivars, 1 native), Indian ricegrass (*Oryzopsis hymenoides*), little bluestem (*Schizachyrium scoparium*), and green needlegrass (*Stipa viridula*). The shrub species included in the mixes were prairie sage (*Artemisia lucoviciana*), fringed sage (*Artemisia frigida*), fourwing saltbush (*Atriplex canescens*), and rubber rabbitbrush (*Chrysothamnus nauseosus*). The herbaceous forb species included in the mixes were purple prairie clover (*Dalea purpurea*), blanketflower (*Gaillardia aristata*), yellow coneflower (*Ratibida columnifera*), and globemallow (*Sphaeralcea spp*). The proportions of grass species remained constant with respect to each other in all four mixtures. The forb and shrub species also were included in constant proportion with respect to each other. The total seeding densities are the same for all mixtures (i.e. approximately 50 kg pure live seed/ha). However, the relative proportion of grasses to forbs and shrubs varied among the mixtures. Mix 1 included half grasses and half forbs and shrubs. Mix 2 included 75% grasses and 25% forbs and shrubs. Mix 3 included 66% grasses and 33% forbs

and shrubs. Mix 4 included only grasses. The species compositions and seeding densities of seed mixtures are detailed in Appendix 2.

Sampling Methods - *Seeded and non-seeded plant abundance*

We established four sampling plots within each treatment plot. Each sampling plot was 6 m x 6 m and located in the center of the 12 m wide treatment plot (Figure 2). Corners of the sampling plots were marked with rebar wrapped in brightly colored flagging tape to facilitate relocation. The corners were marked with colored flags prior to field operations to avoid damaging equipment and shins. The sampling plots at either end of the treatment plots were at least 30 m from the treatment plot end. The remaining two sampling areas were located equidistant from each other and the two end sampling plots. This plot placement ensures that we sample the variation present throughout the treatment plots. The sampling plots were georeferenced using a high precision GPS unit (Ag GPS 114, Trimble Navigation Limited, Sunnyvale, California).

Four 0.5 m^2 sampling subplots were located within each sampling plot, one at each corner of the plot (Figure 3), and the mean of these was used in the statistical analysis. One corner of each subplot corresponded with the corner of the sampling plot, thus, were marked with rebar. These subplot locations will be re-sampled over time. One 0.5 m^2 sampling subplot was placed in the center of each monoculture plot. We counted the individual seedlings of seeded species and estimated the percent aerial cover of all species occurring in each 0.5 m^2 subplot. Presence of species within the 36 m^2 plots that did not occur within the 0.5 m^2 subplots was recorded in order to assess diversity at the larger scale. Correct identification of seedlings of seeded species was facilitated by examining seedlings grown in pots in the greenhouse at CSU and in the monocultures. Mammal scat, burrowing mammal activity and grazing were noted within sampling plots and subplots.

Sampling was done July 19 through August 1, 2006 and was repeated July 6 through July 23, 2007 for Blocks I - V, and August 12 and 13, 2007 for Block VI.

Soil N and C – July 7 and 8, 2006 and July 17 and 18, 2006 one soil sample 0 – 15 cm deep and 2 cm in diameter was collected at the four corners of each sampling plot, as indicated by the red circles in Figure 3, and the samples from each sampling plot were pooled. Total soil C and N were determined for each sample using the LECO CHN1000 (LECO Corporation, St. Joseph, MI, USA) in the Natural Resources Ecology Laboratory facility at Colorado State University (CSU).

Light interception – The reduction of light availability at the soil surface by plant canopy was measured using a light ceptometer (AccuPar LP-80, Decagon Devices, Inc., Pullman, WA, USA) July 13 and 17, 2006 and again in July 11 through 15, 2007. One measurement was made in the middle of each 0.5 m^2 subplot, as indicated in Figure 3, and the mean of the four measurements was used as plot level light interception.

Climate – Precipitation data for was obtained from the NRCS Geospatial Data Gateway web site (http://datagateway.nrcs.usda.gov/).

Species diversity – Changes in species diversity were calculated using both Simpson's index:

$$(N*(N-1))/\sum n_i*(n_i-1),$$

and the Shannon diversity index:

$$((N*(\ln N)-\sum(n_i*\ln(n_i)))/N,$$

where N is the total amount of cover for all species and n_i is the amount of cover for the i^{th} species. Both indices were computed for the overall site, each seed mix, seeded species, non-seeded species, non-seeded native species and non-seeded non-native species.

Statistical Analysis - Abundances of seeded and non-seeded plants, cover of litter and bare ground, and percent carbon (C) and nitrogen (N) were analyzed using analysis of variance models (SAS version 9.1 and JMP version 5.0.5.1, SAS Institute, Inc., Cary, NC) that included block, seed mixture and their interaction. For 2006 data, when raw data were ill-conditioned, results of analyses on raw data were similar to those of log transformed data, thus, results from analysis of the former are reported. The same was true for 2007 data, with the exception of seeded species data, which were ln + 1 transformed for analyses.

Simple linear regression was used to evaluate the performance of seeded species with respect to abundance of species that were not seeded (non-seeded species), cover of litter (log transformed for 2006 data) and bare ground, light interception (log transformed for 2006 data), and soil C and N. Student's t or Tukey's least significant differences were employed for mean separations. Statistical significance was set at $\alpha = 0.05$.

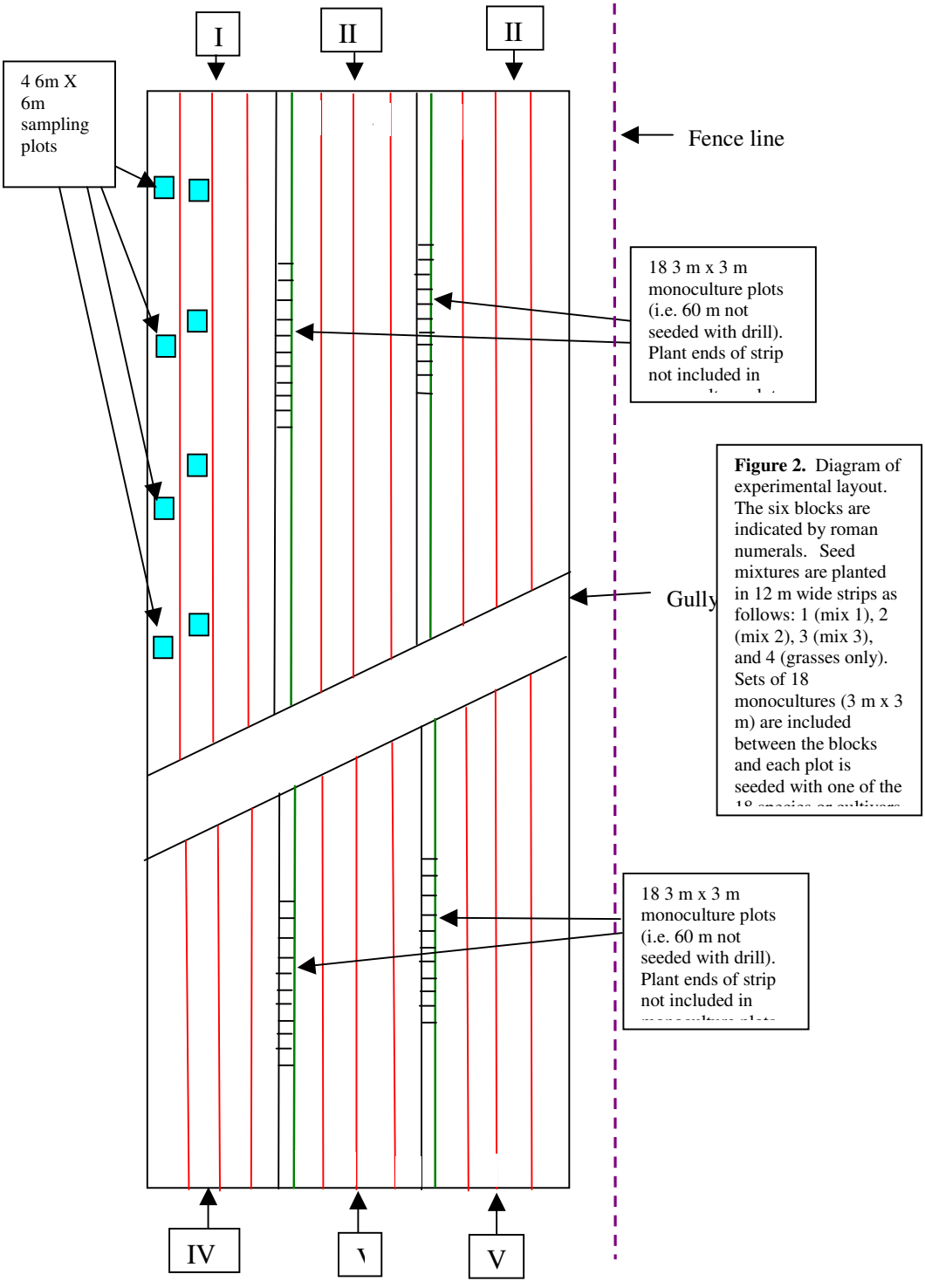


Figure 2. Experimental design and layout.

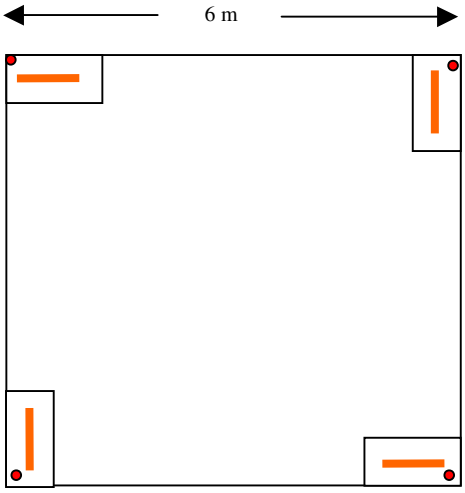


Figure 3. Sampling area layout. 0.5 m^2 subplots (0.5 x 1.0 m) were placed at the corners of the 6 m x 6 m plots. Soil samples were taken at the locations indicated by the red circles for total N and C measurements. Light interception was measured in the center of each 0.5 m^2 subplot, as indicated by the orange bar. Plant species were monitored within the 36 m^2 area.

RESULTS

Seeded Species

Species encountered during sampling and abbreviations for their names used throughout the following figures are listed in Table 1. The cover of seeded species (Figure 4) was highly correlated with density of seeded species (Figure 5) in 2006 and 2007 ($P < 0.0001$, $R^2 = 0.81$ and $P < 0.0001$, $R^2 = 0.73$, respectively), thus, only analyses of cover are presented. Cover of seeded species was much lower than non-seeded species in both years, and doubled in 2007 (Figure 6). There was no correlation between the abundance of seeded and non-seeded species in 2006 ($P = 0.59$, $R^2 = 0.003$), and a negative correlation in 2007 ($P < 0.0001$, $R^2 = 0.45$). There was a tendency for cover of seeded species to be lower in plots with high litter in 2006 (Figure 6a, $P = 0.08$, $R^2 = 0.03$)), a relationship that became stronger in 2007 (Figure 6b, $P = 0.01$, $R^2 = 0.07$). There was no relationship between cover of seeded species and bare ground in 2006 (Figure 6a, $P = 0.10$, $R^2 = 0.03$), and a negative relationship in 2007 (Figure 6b, $P = 0.0002$, $R^2 = 0.14$).

Table 1. Species names and abbreviations. Non-seeded species in bold are native to Colorado.

Common name	Variety	Scientific Name	Code
Seeded Species			
Fringed sage		*Artemisia frigida*	ARTFRI
Prairie sage		*Artemisia ludoviciana*	ARTLUD
Fourwing saltbush		*Atriplex canescens*	ATRCAN
Sideoats grama	"Vaughn"	*Bouteloua curtipendula*	BOUCUR
Blue grama	Native	*Bouteloua gracilis*	BOUGRA
Buffalograss	"Texoka"	*Buchloe dactyloides*	BUCDAC
Rubber rabbitbrush		*Chrysothamnus nauseosus*	CHRNAU
Purple prairie clover, Kanab		*Dalea purpurea*	DALPUR
Slender wheatgrass	"San Luis"	*Elymus trachycaulus*	ELYTRA
Blanketflower		*Gaillardia aristata*	GAIARS
Junegrass	Native	*Koeleria macrantha*	KOEMAC
Indian ricegrass	"Rimrock"	*Oryzopsis hymenoides*	ORYHYM
Western wheatgrass	"Arriba"	*Pascopyrum smithii*	PASSMA
Western wheatgrass	“Native”	*Pascopyrum smithii*	PASSMN
Yellow coneflower		*Ratibida columnifera*	RATCOL
Little bluestem	"Camper"	*Schizachyrium scoparium*	SCHSCO
Globemallow		*Sphaeralcea spp*	SPHSP
Green needlegrass	"Lodorm"	*Stipa viridula*	STIVIR
Non-seeded Species			
prostrate pigweed		*Amaranthus blitoides*	AMABLI
redroot pigweed		*Amarathus retroflexus*	AMARET
prickly poppy		***Argemone polyanthemos***	**ARGPOL**
wild oat		*Avena fatua*	AVAFAT
field brome		*Bromus arvensis*	BROARV
cheatgrass		*Bromus tectorum*	BROTEC
littlepod false flax		*Camelina microcarpa*	CAMMIC
musk thistle		*Carduus nutans*	CARNUT
prostrate or spotted spurge		*Chamaesyce maculata*	CHAMAC
creeping spurge		*Chamaesyce serpens*	CHASER
common lambsquarters		*Chenopodium album*	CHEALB
		Chenopodium berlandieri	CHEBER
		Chenopodium sp1	CHESP1
Canada thistle		*Cirsium arvense*	CIRARV
poison hemlock		*Conium maculatum*	CONMAC
hare's ear mustard		*Conringia orientalis*	CONORI
field bindweed		*Convolvulus arvensis*	CONARV
hounds tongue		*Cynoglossum officinale*	CYNOFF
flixweed		*Descurainia sophia*	DEXSOP

toothed spurge	*Euphorbia dentata*	POIDEN
snow-on-the-mountain	***Euphorbia marginata***	**EUPMAR**
beeblossom	***Gaura L.***	**GAU**
annual sunflower	***Helianthus annuus***	**HELANN**
foxtail barley	*Hordeum jubatum*	HORJUB
kochia	*Kochia scoparia*	KOCSCO
prickly lettuce	*Lactuca serriola*	LACSER
western sticktight	***Lappula occidentalis***	**LAPOCC**
pineappleweed	*Matricaria matricarioides*	MATMAT
alfalfa	*Medicago sativa*	MEDSAT
	Nutalia nuda	NUTNUD
witchgrass	*Panicium capillare*	PANCAP
Virginia ground cherry	*Physalis virginiana*	PHYVIR
devils shoe string	*Polygonum arenastrum*	POLARE
wild buckwheat	*Polygonum convolvulus*	POLCON
	Polygonum ramosissimum	POLRAM
slimflower scurf pea	***Psoralidium tenuiflorum***	**PSOTEN**
wild rose	***Rosa* sp.***	**ROSMUL**
Russian thistle	*Salsola iberica*	SALIBE
lanceleaf sage	***Salvia reflexa***	**SALREF**
butterweed, golden ragwort	*Senecio sp.1*	SENSP1
tumble mustard	*Sisymbrium altissimum*	SISALT
buffalobur	*Solanum rostratum*	SOLROS
cut-leaved nightshade	*Solanum triflorum*	SOLTRI
spiny sowthistle	*Sonchus asper*	SONASP
sand drop seed	***Sporobolus cryptandrus***	**SPOCRI**
white heath aster	***Symphyotrichum ericoides***	**SYMERI**
salsify sp	*Tragopogon sp1*	TRASP1
salsify sp	*Tragopogon sp2*	TRASP2
cow cockle	*Vaccaria pyramidata*	VACPYR
common mullein	*Verbascum thapsus*	VERTHA
prostrate vervain	***Verbena bracheata***	**VERBRA**
crownbeard, crow pen daisy	***Ximenesia encelioides***	**XIMENC**
Unknowns		
common ground cherry		
unk sp1		
unk sp2		
unk sp3		

***** Probably *Rosa woodsii*, not *R. multiflora*, which is exotic.

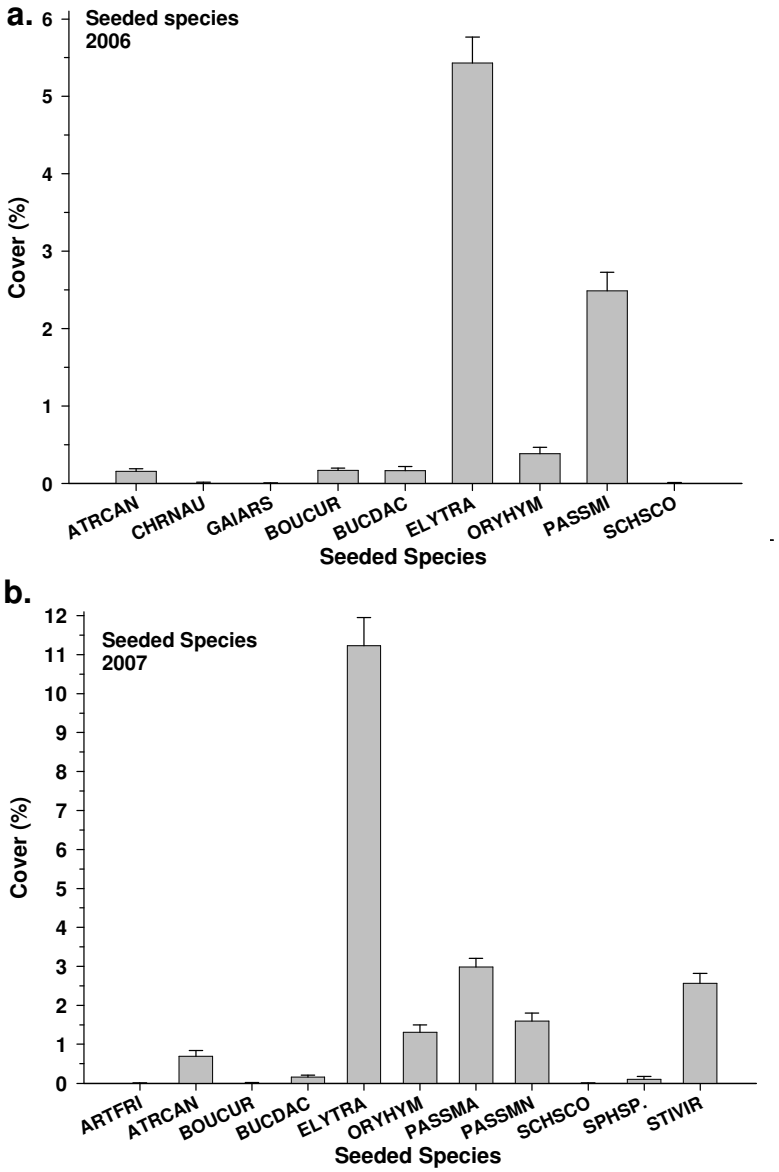


Figure 4. Mean cover of seeded species (± one standard error of the mean) for (a) 2006 and (b) 2007. Species are fourwing saltbush (*Atriplex canescens,* ATRCAN), fringed sage (*Artemisia frigid,* ARTFRI), sideoats grama (*Bouteloua curtipendula,* BOUCUR), buffalo grass (*Buchloe dactyloides*, BUCDAC), slender wheatgrass (*Elymus trachycaulus*, ELYTRA), indian ricegrass (*Oryzopsis hymenoides*, ORYHYM), western wheatgrass "Arriba" (*Pascopyrum smitthii* Arriba", PASSMA), western wheatgrass "native" (*P. smithii* "Native", PASSMN), scarlet globemallow (*Sphaeralcea coccinea*, SPHCOC) and green needlegrass (*Stipa viridula*, STIVIR). Globemallow green needlegrass were present in 2007, but not 2006, while blanket flower was present in 2006, but not 2007. In 2006, we were unable to distinguish between the two western wheatgrass accessions, thus we these species were combined into PASSMI. Bars are mean ± one standard error of the mean. *Note*: All 96 plots were included in these mean calculations.

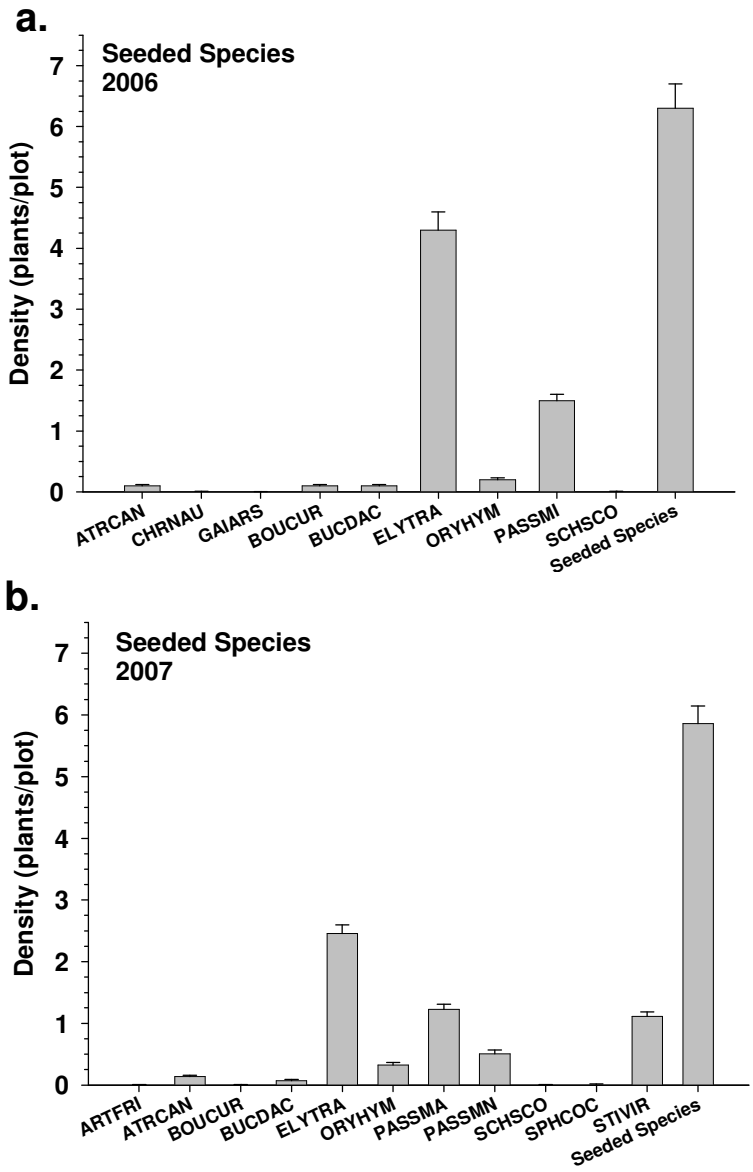


Figure 5. Mean density of seeded species (± one standard error of the mean) for (a) 2006 and (b) 2007. Species are fourwing saltbush (*Atriplex canescens,* ATRCAN), fringed sage (*Artemisia frigid,* ARTFRI), sideoats grama (*Bouteloua curtipendula,* BOUCUR), buffalo grass (*Buchloe dactyloides*, BUCDAC), slender wheatgrass (*Elymus trachycaulus*, ELYTRA), indian ricegrass (*Oryzopsis hymenoides*, ORYHYM), western wheatgrass "Arriba" (*Pascopyrum smitthia* "Arriba", PASSMA), western wheatgrass "native" (*P. smithii* "Native", PASSMN), scarlet globemallow (*Sphaeralcea coccinea*, SPHCOC) and green needlegrass (*Stipa viridula*, STIVIR). Scarlet globemallow green needlegrass were present in 2007, but not 2006, while blanket flower was present in 2006, but not 2007. In 2006, we were unable to distinguish between the two western wheatgrass accessions, thus we combined both into PASSMI. Bars are mean ± one standard error of the mean. *Note*: All 96 plots were included in these mean calculations.

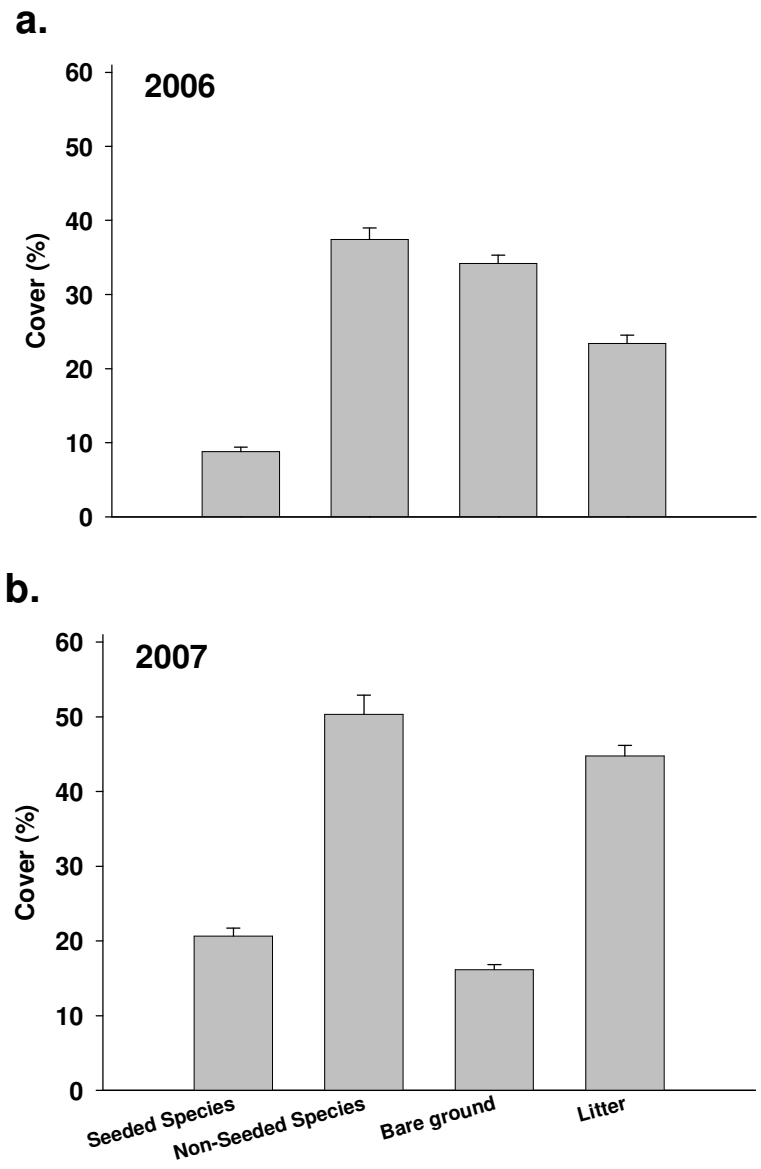


Figure 6. Mean cover of seeded species, non-seeded species, litter and bare ground in (a) 2006 and (b) 2007. Bars are mean ± one standard error of the mean. *Note*: All 96 plots were included in these mean calculations.

In 2006 and 2007 the cover of seeded species in each of the seed mixture treatments depended on location in the field (significant Block x Seed Mixture interaction, Table 2, Figure 7). In 2006, seeded species in Mix 1 (50% grass) had higher cover than other seed mixtures in Block V, but had much lower cover than other mixtures in Blocks I, II, III and VI. Low cover in Blocks I and II can be attributed to seeder malfunction. Cover of seeded species in each of the seed mixtures also depended on field location in 2007 (Table 2b, Figure 8a). Plots from Blocks I and II, Mix 1 were not included in the 2007 analyses because the grass box of the seeder malfunctioned when they were being planted. *Note:* For the final report, the 2006 analyses will be repeated excluding these plots and graphs will be corrected to reflect the change.

Table 2a. ANOVA table for seeded species in 2006 (α=0.05). *Note:* Data were not transformed prior to analysis.

Factor	df	Seeded species		BOUCUR		BUCDAC		ELYTRA		ORYHYM		PASSMI	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Block	5	5.9	0.0001	4.4	0.001	3.2	0.01	2.85	0.02	1.37	0.24	5.63	0.0002
Seed Mixture	3	19.5	<0.0001	0.37	0.78	4.15	0.009	17.42	<0.0001	0.88	0.46	12.98	<0.0001
Block x Seed Mixture	15	4.4	<0.0001	1.60	0.10	1.76	0.06	3.41	0.0002	0.86	0.60	2.34	0.009

Table 2b. ANOVA table for seeded species in 2007 (α=0.05). *Note:* Data were natural log + 1 transformed prior to analysis.

Factor	df	Seeded species		BUCDAC		ELYTRA		ORYHYM		PASSMA		PASSMN		STIVIR	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Block	5	8.79	<0.0001	6.89	0.0004	10.21	<0.0001	1.61	0.20	1.73	0.17	1.77	0.16	3.59	0.02
Seed Mixture	3	0.11	0.89	0.12	0.89	0.42	0.66	1.93	0.15	0.23	0.80	1.14	0.32	0.90	0.41
Block x Seed Mixture	15	2.79	0.003	1.26	0.26	1.92	0.04	1.45	0.16	1.68	0.08	1.26	0.26	2.45	0.009

Seven of the ten grass species planted were observed at least once in 2006, and nine in 2007. The grasses comprised the majority of the seeded species cover (Figure 4a and b). In 2006, cover of the most successful seeded grasses (slender wheatgrass and western wheatgrass) in each of the seed mixture treatments depended on location (Table 2, Figure 7b and c). In Mix 2

(75% grass) and Mix 4 (100% grass) they had lower cover when located in Blocks IV and V than when located in Blocks II and III. These species had very low cover in Mix 1 when located in Blocks I and II, which can be attributed to mechanical malfunction of the seeder that resulted in lower grass seeding rates in Blocks I, II, 10 feet of Block III, and the seeded areas at the end of the monoculture strips between Blocks II and III, but their cover in this mixture was similar in Blocks III, IV, V and VI. In 2007, performance of slender wheatgrass and green needlegrass in each of the seed mixture treatments depended on field location (Table 2b, Figure 8b and c).

Averaging across seed mixture treatments, cover of sideoats grama and buffalograss were affected by location (i.e. significant Block effect) in 2006 (Table 2a, Figure 9a). Sideoats grama had greater cover in Block VI than other blocks, while buffalo grass had greater cover in Block II than other blocks. In 2007, only buffalo grass cover was related to field location (Table 2b, Figure 10a). Its cover was greater in Block VI than Blocks III, IV and V, which were greater than Blocks I and II, the latter having the lowest cover of all. Sideoats grama occurred in only one plot in 2007. In 2006, cover of buffalo grass in Mix 4 (100% grass) was similar to Mix 3 (66% grass) and greater than Mixes 1 (50% grass) and 2 (75% grass) (Table 2a, Figure 11).

Indian ricegrass occurred in 40 subplots in 2006 and 102 subplots in 2007, but no relationship between location (i.e. Block) and seed mixture treatment could be detected in either year (Table 2a and b). Western wheatgrass "Arriba" and "Native" occurred in 250 and 129 sub-plots, respectively, in 2007, but no relationship between location and seed mixture treatment could be detected (Table 2b). Little bluestem was observed in only three plots in 2006 and one plot in 2007, thus effects of location and seed mixture treatments are not biologically meaningful.

Two of the four shrub species and one of the four forb species were observed in 2006 (Figure 4a). In that year, fourwing saltbush was present in 28 plots, while rubber rabbitbrush and blanketflower were present in only one plot each. Blanket flower was not present in 2007, but globemallow was detected for the first time. No meaningful statistical analyses could be conducted on the latter three species due to low frequency. In 2006, cover of fourwing saltbush was greater in Blocks II and III than the other blocks (Figure 10a). It was not seeded in Mix 4 (100% grass), thus, its cover was greater in the three seed mixtures in which it was included in 2006 (Figure 11). In 2007, the pattern was less clear in that Mix 1 (50% grass) had lower cover of fourwing saltbush than Mix 4 (100% grass), which was not different than Mix 2 (75% grass). Mix 3 (66% grass) had the greatest cover of fourwing saltbush, but not significantly more than Mix 2 (Figure 12).

The cover of seeded species was negatively associated with cover of non-seeded species ($R^2 = 0.45$, $P < 0.0001$, Coefficient = -0.28).

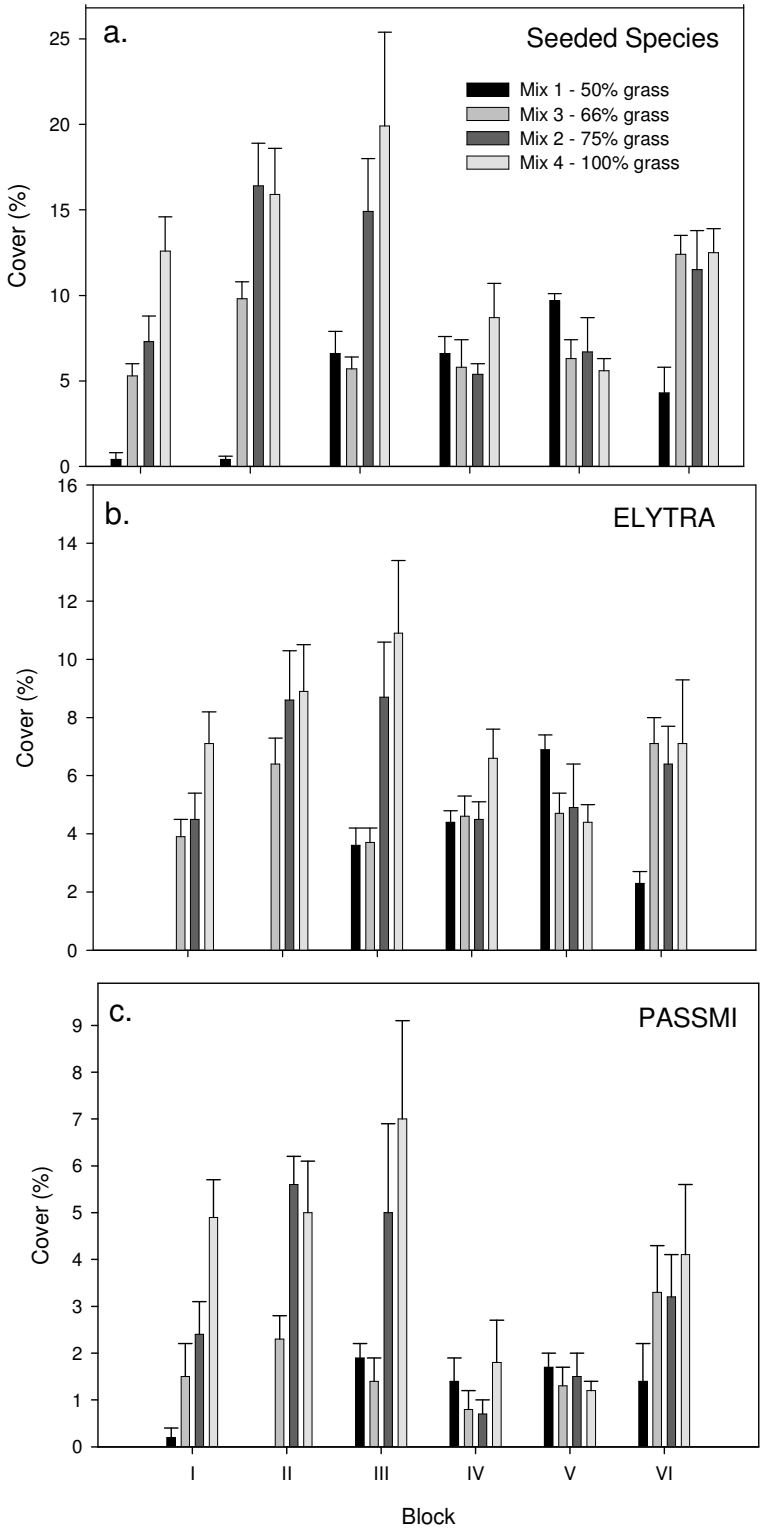


Figure 7. Cover of seeded species with significant Block x Seed mixture interaction in ANOVA in 2006: (a) all seeded species, (b) *Elymus trachycaulus* (ELYTRA), and (c) *Pascopyrum smithii* (PASSMI). *Note:* All 96 plots were included in these analyses.

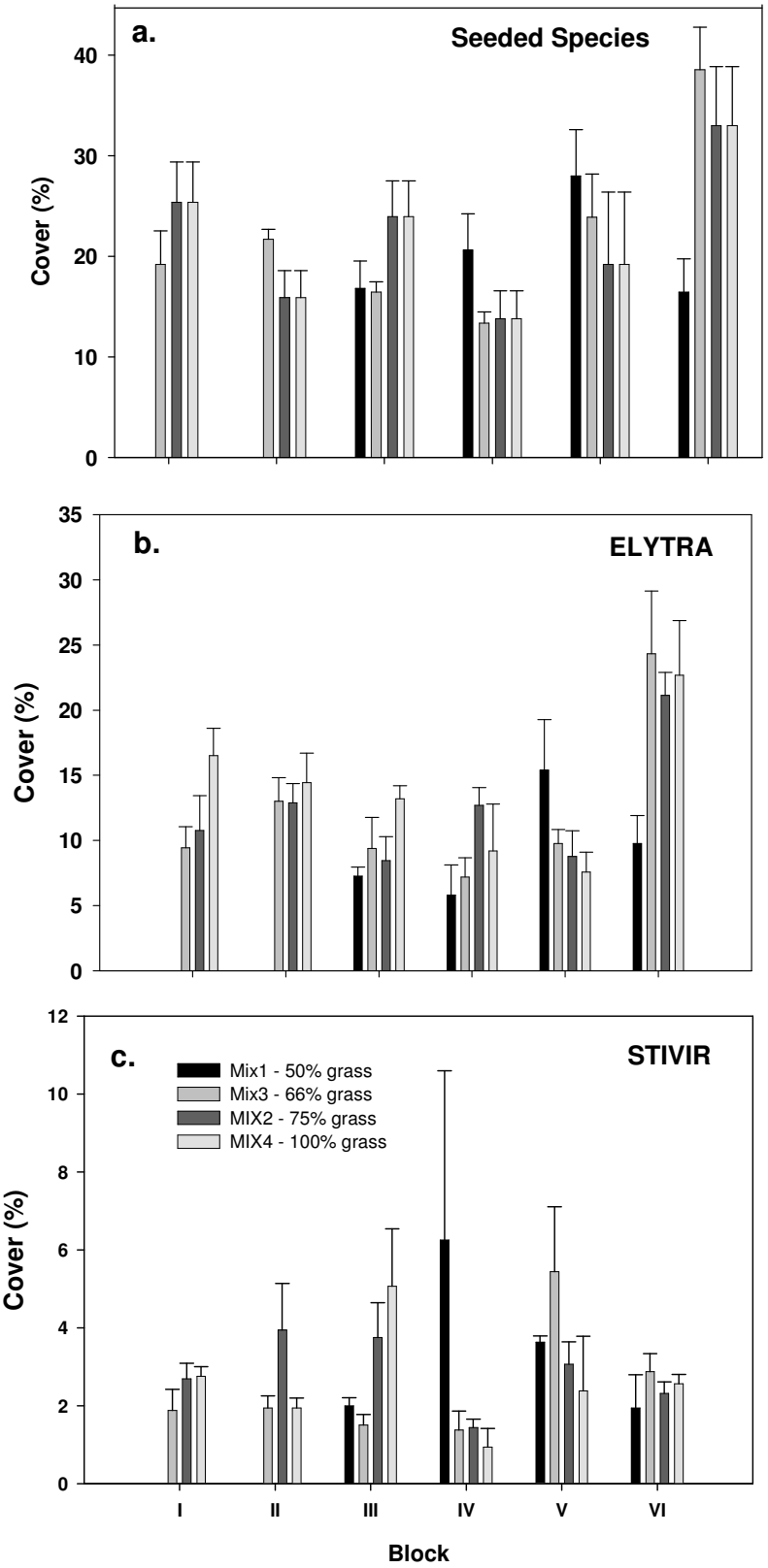


Figure 8. Cover of seeded species with significant Block x Seed mixture interaction in ANOVA in 2007: (a) all seeded species, (b) *Elymus trachycaulus* (ELYTRA), and (c) *Stipa viridula* (STIVIR). *Note:* Block I and II, Seed mix 1 were omitted due to seeder malfunction.

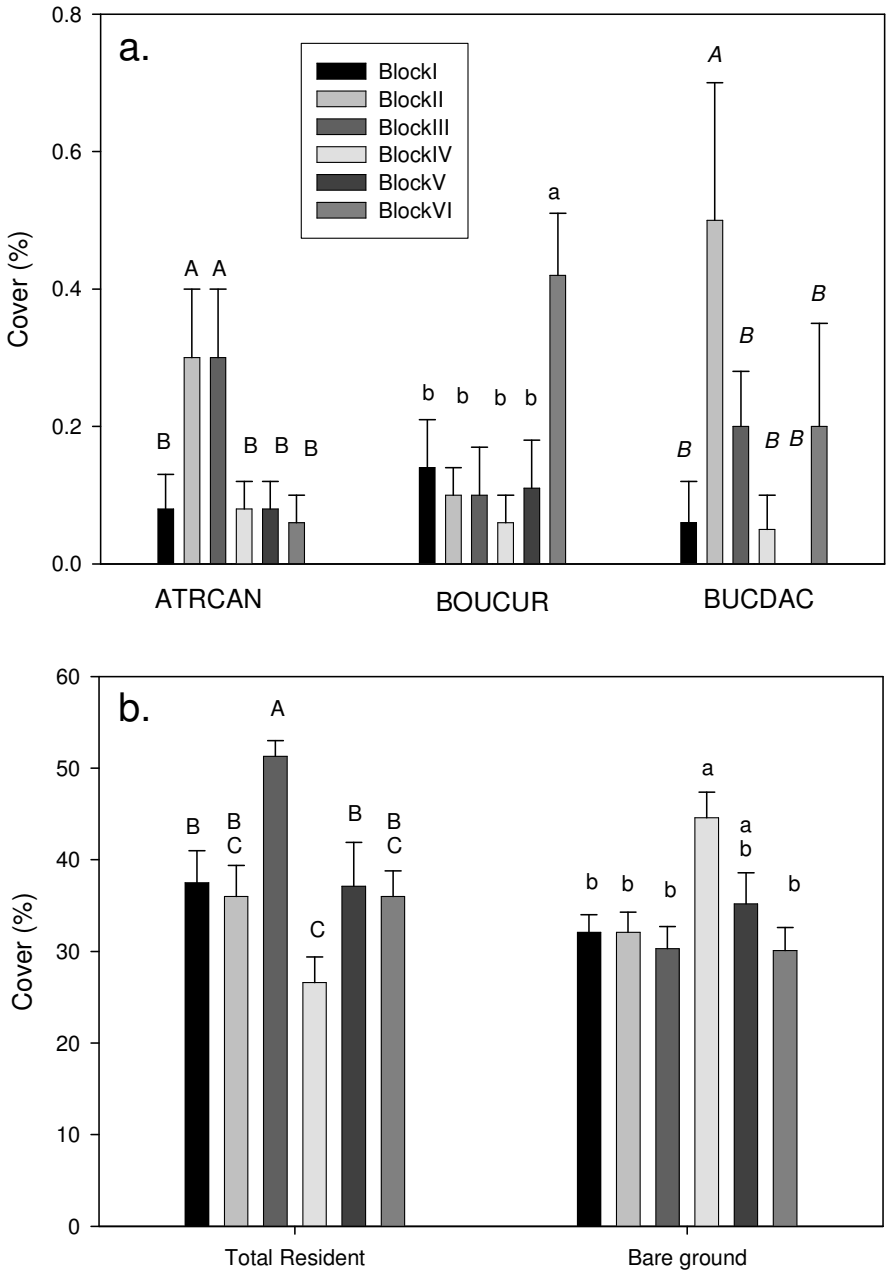


Figure 9. Cover of (a) seeded species and (b) non-seeded species and other factors with significant Block effects in ANOVA in 2006. Means with different letters are significantly different at $\alpha = 0.05$.

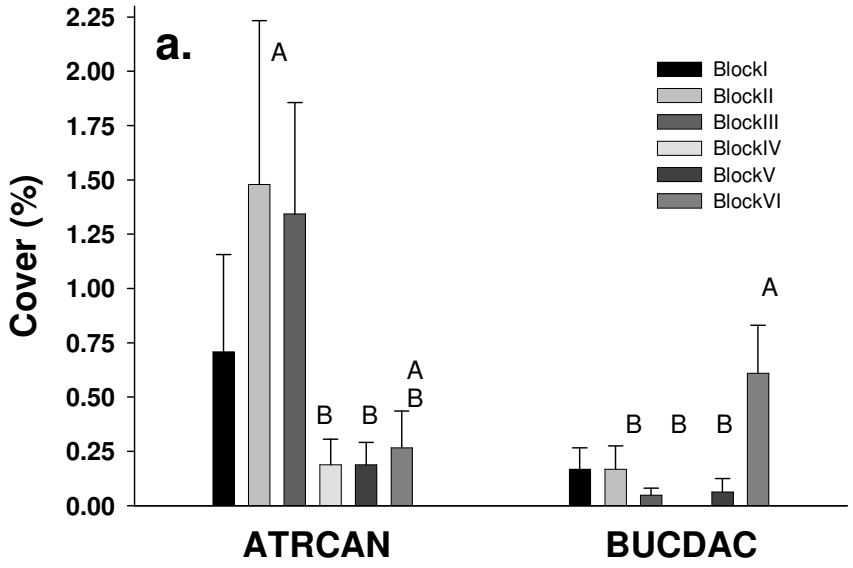


Figure 10. Cover of seeded species with significant Block effects in ANOVA in 2007. Means with different letters are significantly different at $\alpha = 0.05$.

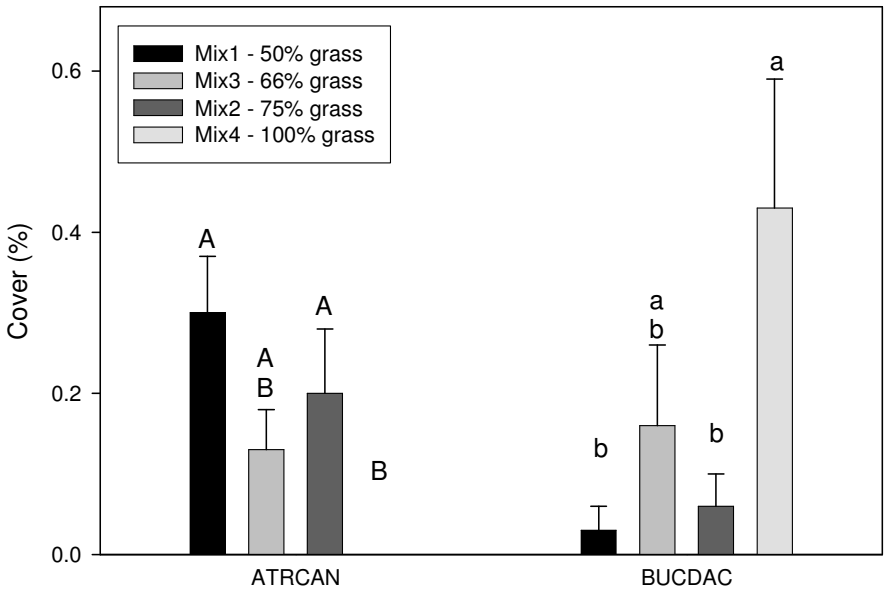


Figure 11. Cover of seeded species with significant seed mixture effects in ANOVA in 2006. Means with different letters are significantly different at $\alpha = 0.05$.

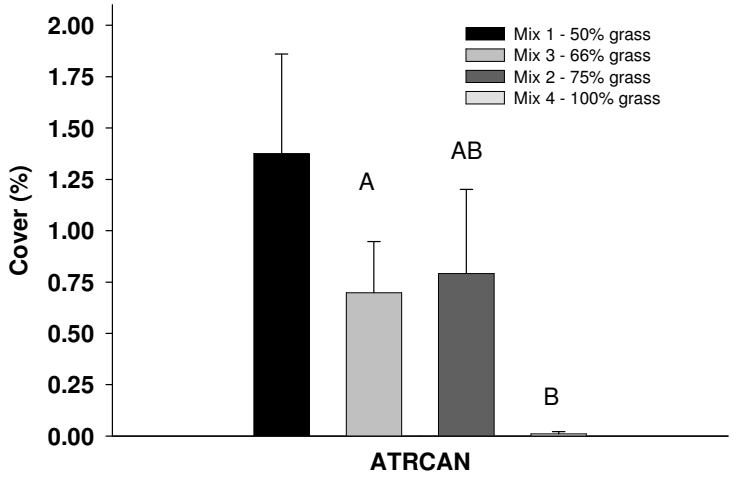


Figure 12. Cover of fourwing saltbush, the only seeded species with significant seed mixture effects in ANOVA in 2007. Means with different letters are significantly different at $\alpha = 0.05$. Mean separation was not estimable for Seed Mixture 1 due to missing data.

Non-Seeded Species

Twenty nine non-seeded species were found in the sampling plots in 2006 (Table 1, Figure 13), and 21 non-seeded species were found in 2007 (Table 1, Figure 14). Cover of non-seeded species differed among locations (Blocks), but not among seed mixture treatments in 2006 (Table 3a, Figure 9b). Block III had greater non-seeded species cover than any other block. Non-seeded cover in Block IV was lower than Block I and V, but not different from Blocks II and VI. In 2007, the cover of non-seeded species in different blocks depended on seed mix (significant Block x Seed Mixture interaction, Table 3b, Figure 15a). Cover of non-seeded species appeared to be greatest for Mixes 2, 3 and 4 in Block VI. Mix 1 had greater cover of non-seeded species than the other seed mixture treatments only in Block V.

Twelve of the non-seeded species were native (Table 1), but occurred in such small amounts that we were not able to statistically analyze their abundances. Four non-seeded species had average cover greater than one percent in 2006 and six species in 2007; analyses will focus on them (Figure 13a, 14a). Field bindweed was the most abundant non-seeded species in 2006 and 2007. Cover of field bindweed in 2006 was greater in Block I and III than any other blocks

and greater in Block II than Blocks IV, V and VI (Table 3a, Figure 16). Cover of field bindweed in Blocks depended on seed mixture treatment (i.e. significant Block x Seed Mixture interaction, Table 3b, Figure 15b) in 2007. Russian thistle was an abundant non-seeded species in both 2006 and 2007. The cover of Russian thistle was greater in Blocks V and VI than any other blocks and was similar in Blocks II and IV in 2006 (Table 3a). Blocks I and III had Russian thistle cover similar to Block II, but less than Block IV (Table 3a, Figure 16). In 2007 its cover in blocks depended on seed mixture treatment (i.e. significant Block x Seed Mixture interaction, Table 3b, Figure 15c). Kochia had cover of less than 1% in 2006 (Figure 13b) and it was detected in only 13 of the 96 plots, although it dominated the vegetation in parts of the field. In 2007, it was detected in 63 plots and its cover was just over 1% (Figure 14a). Its cover did not differ among blocks or seed mixture treatments this year (Table 3b). Prickly lettuce occurred in both years, but had cover greater than 1% only in 2007 (Figure 14a). In that year, its cover depended on location (i.e. Block) (Table 3b, Figure 17a) and was lowest in Block VI. Its cover was also affected by seed mixture treatment (Table 3b) and it was more abundant in Seed Mixture 3 than Seed Mixture 4 (Figure 18).

Table 3a. ANOVA table for most abundant non-seeded species in 2006 (α=0.05).

Factor	df	Non-Seeded		CHESP1		CONARV		SALIBE		SOLTRI	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Block	5	4.93	0.0006	14.76	<0.0001	24.11	<0.0001	10.99	<0.0001	5.76	0.0002
Seed Mixture	3	1.78	0.16	1.34	0.27	2.37	0.08	1.41	0.25	1.43	0.24
Block x Seed Mixture	15	0.69	0.78	2.04	0.02	1.08	0.039	0.39	0.98	0.91	0.56

Table 3b. ANOVA table for most abundant non-seeded species in 2007 (α=0.05).

Factor	df	Non-Seeded		CONARV		CONORI		LACSER		KOCSCO		SALIBE		SISALT	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Block	5	0.93	0.43	11.47	<0.0001	0.84	0.48	5.06	0.003	1.04	0.38	14.48	<0.0001	3.51	0.02
Seed Mixture	3	15.12	<0.0001	0.97	0.38	0.68	0.51	5.64	0.005	1.37	0.26	4.08	0.02	2.19	0.12
Block x Seed Mixture	15	3.67	0.0002	2.71	0.004	0.87	0.59	1.17	0.32	1.71	0.08	6.32	<0.0001	1.01	0.45

Some non-seeded species were detected only in 2006. The cover of *Chenopodium* sp. in different seed mixture treatments depended on location (i.e. Block) that year (Table 3, Figure 19). The cover of this species in Block III was greater than in any other block and it was concentrated on the east side of the block. The cover of cut-leaved nightshade, which also only occurred in 2006, increased progressively from Block I to Block VI (Table 3, Figure 16).

Some non-seeded species were detected only in 2007. One of these species, hare's ear, had cover greater than 1% in 2007, but was unaffected by location or seed mixture treatments (Table 3b). Tumble mustard also occurred only in 2007. Its cover was greater in Blocks I and II, although mean separation tests could not be conducted due to missing data.

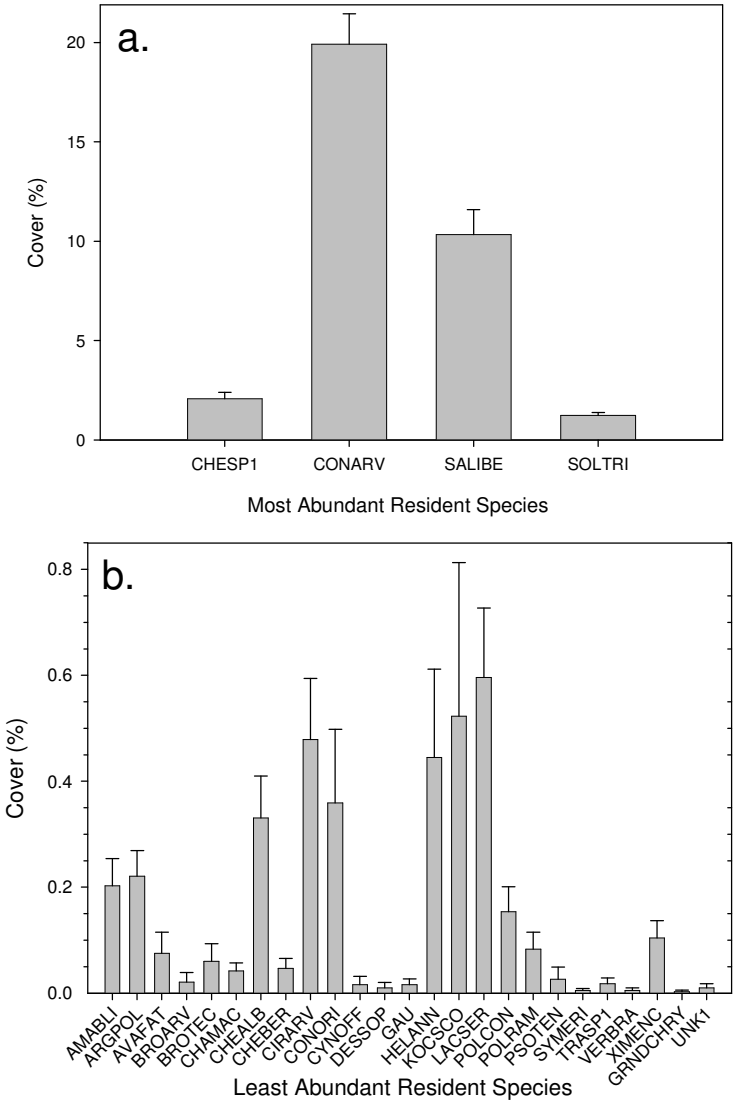


Figure 13. Mean cover in 2006 of (a) most abundant and (b) least abundant non-seeded species ± one standard error of the mean. *Note:* Block I and II, Seed mix 1 were omitted due to seeder malfunction.

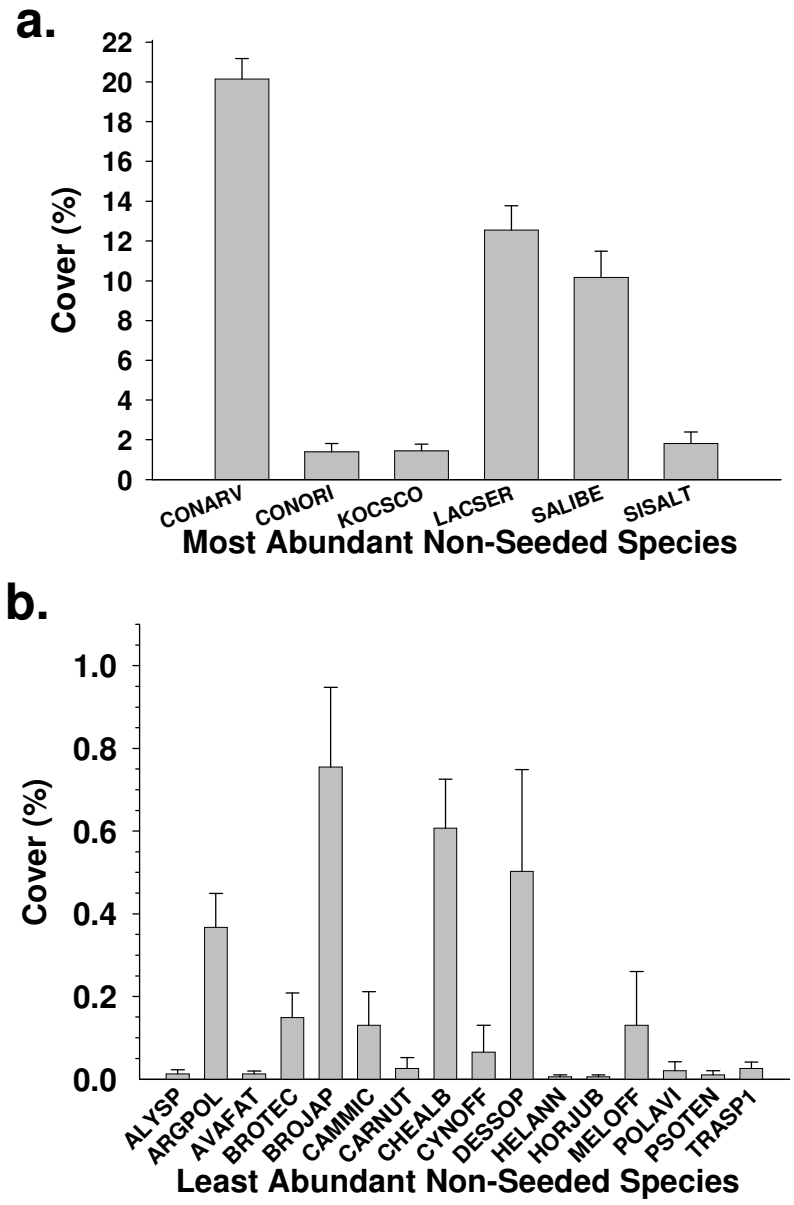


Figure 14. Mean cover in 2007 of (a) most abundant and (b) least abundant non-seeded species ± one standard error of the mean.

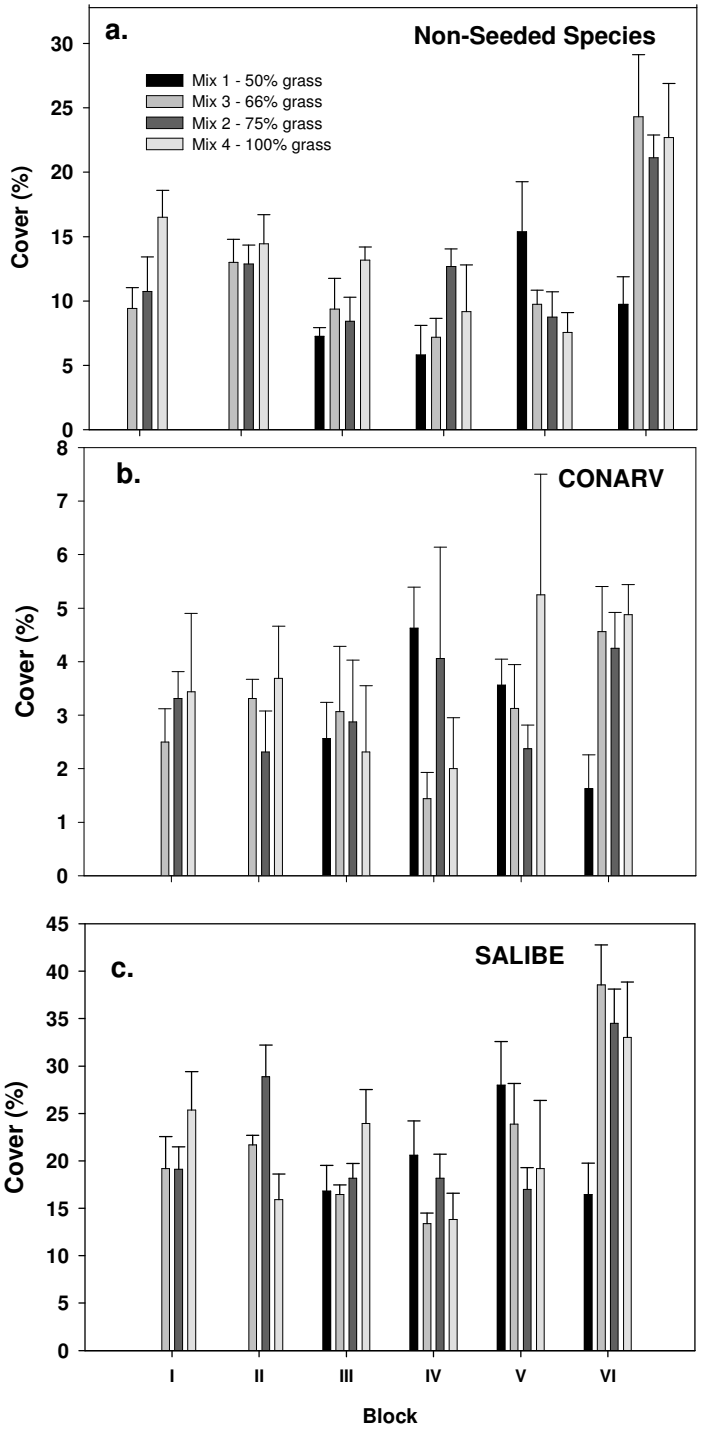


Figure 15. Cover of non-seeded species and field bindweed and Russian thistle (two abundant non-seeded species) by block and seed mixture in 2007 (bars are mean ± one standard error of the mean).

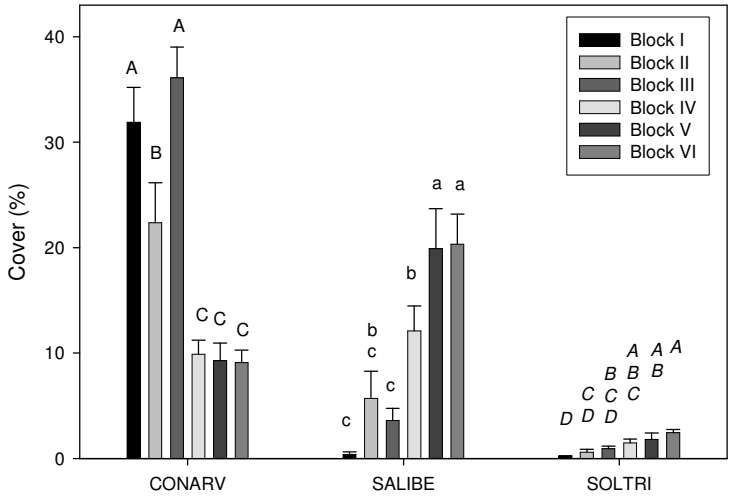
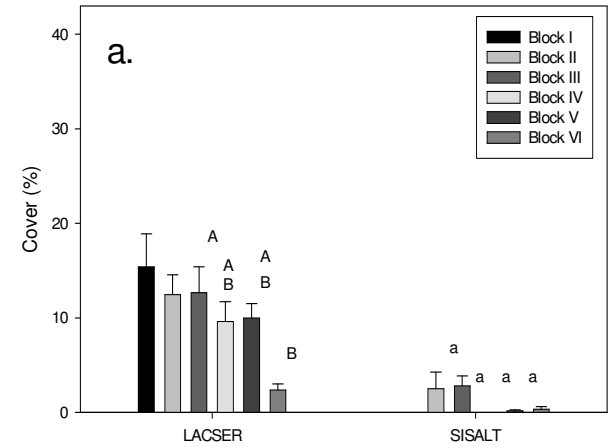
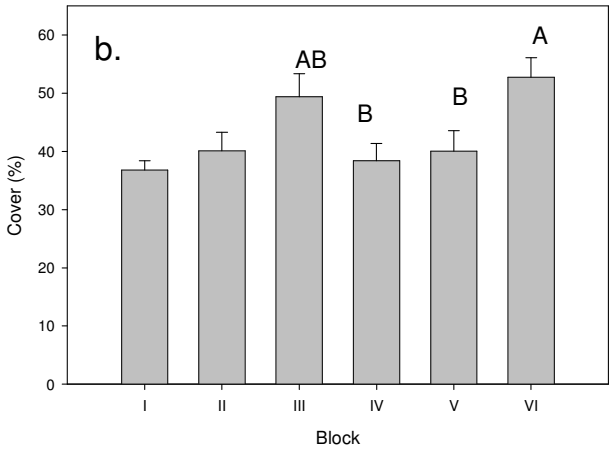


Figure 16. Cover of abundant non-seeded species by block in 2006. Bars are mean ± one standard error of the mean. Means with different letters are significantly different at $\alpha = 0.05$.





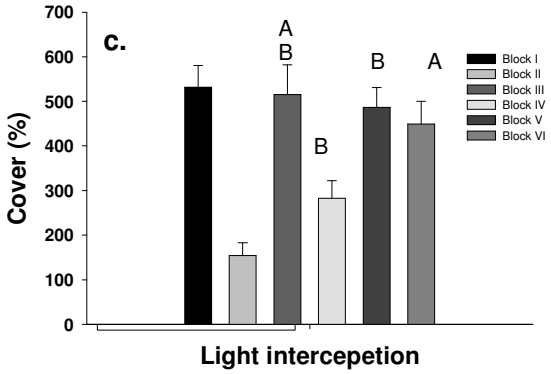


Figure 17. Cover of (a) non-seeded species, (b) litter, and (c) light interception by block for 2007. Means with different letters are significantly different at $\alpha = 0.05$. Mean separation tests were not estimable for Blocks I and II due to missing data.

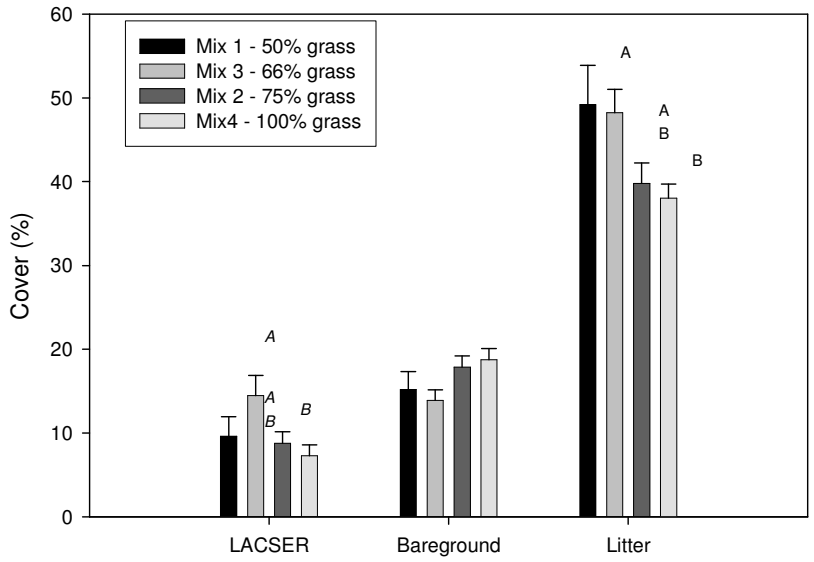


Figure 18. Cover of prickly lettuce (LACSER), bareground and litter by seed mixture for 2007. Means with different letters are significantly different at $\alpha = 0.05$. Mean separation tests were not estimable for Mix 1 due to missing data.

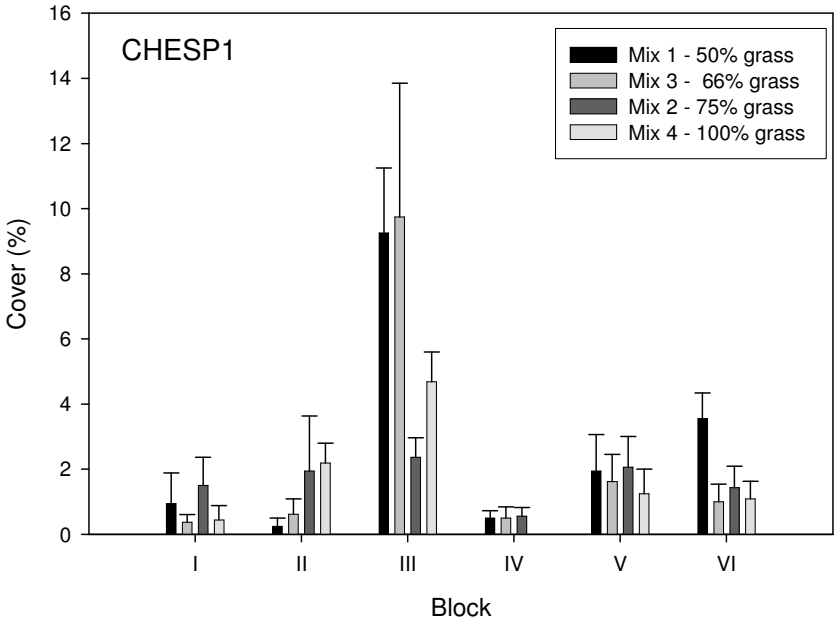


Figure 19. Cover of *Chenopodium* sp. by block and seed mixture in 2006 (bars are mean ± one standard error of the mean).

Abiotic factors

We detected no effects of location (i.e. Block) and seed mixture treatment on cover of litter and light interception by the plant canopy in 2006 (Table 4a). In 2007, light interception was greater in Blocks V and VI than Block IV. Although mean separation tests were not estimable due to missing data, the light interception was lowest in Block II (Figure17c). In 2007, cover of litter was greater in Block VI than Blocks IV and V, (and probably greater than in Blocks I and II, although mean separations were not estimable), but not different than Block III (Table 4b, Figure 17b). In 2007, cover of litter was greater in Seed Mixture 3 than Seed Mixture 4 (Table 4b, Figure 18). In 2006, cover of bare ground in Block IV was similar to Block V, but higher than Blocks I, II, III, and VI (Table 4a, Figure 9b). These differences were not seen in 2007. Instead, cover of bare ground differed among seed mixture treatments, but mean separation tests were inconclusive due to missing data (Table 4b, Figure 18).

We detected no differences in percent nitrogen (N) among blocks or seed mixes (Table 4a). Percent carbon (C) differed among blocks (Table 4a, Figure 20).

Table 4a. ANOVA for abiotic factors in 2006 (n=96 for light interception, litter and bareground, n=88 for soil %C and %N) α=0.05.

Factor	df	Light Interception		Litter		Bare ground		Soil % C		Soil % N	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Block	5	1.0	0.4	2.2	0.1	4.4	0.002	32.15	<0.0001	1.66	0.18
Seed Mixture	3	2.0	0.1	2.0	0.13	0.2	0.9	0.73	0.49	1.64	0.20
Block x Seed Mixture	15	0.7	0.7	1.4	0.2	0.6	0.8	0.22	1.0	0.38	0.97

Table 4b. ANOVA for abiotic factors in 2007 (n=88) α=0.05.

Factor	df	Light Interception		Litter		Bare ground	
		F	*P*	F	*P*	F	*P*
Block	5	7.87	0.001	6.00	0.001	1.45	0.24
Seed Mixture	3	0.81	0.37	5.46	0.006	3.57	0.03
Block x Seed Mixture	15	1.74	0.08	1.61	0.10	0.93	0.53

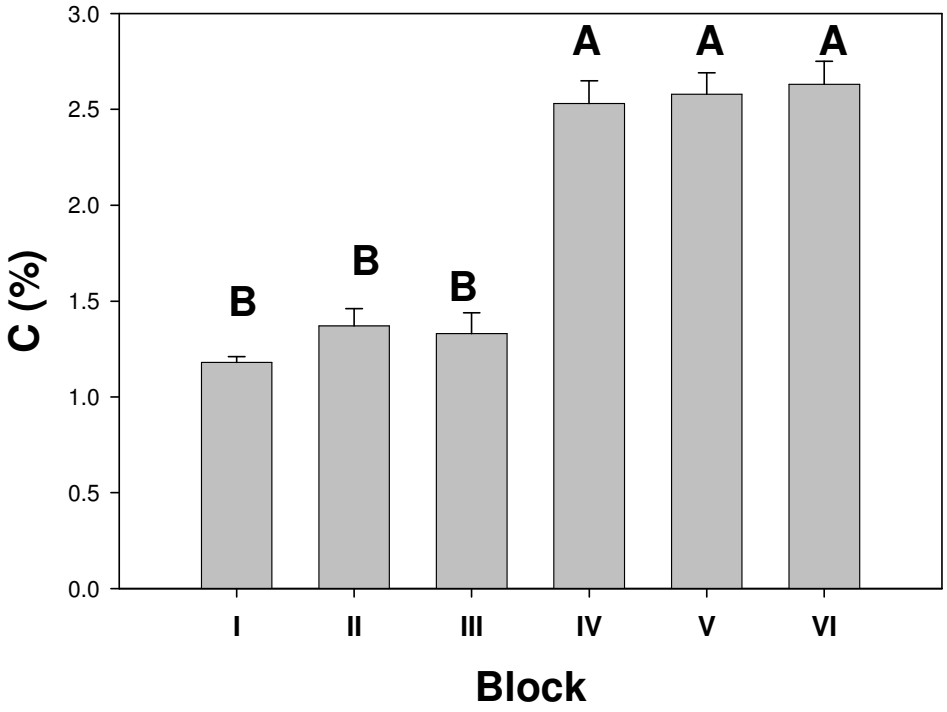


Figure 20. Soil percent carbon in experimental blocks in 2006. Means with different letters are significantly different at $\alpha = 0.05$.

In 2006, percent C was correlated with cover of non-seeded species, but percent N was not and neither percent C nor percent N were correlated with cover of seeded species (Table 5a, Figure 21). There was no relationship between cover of seeded species and bare ground and litter in 2006, whereas non-seeded species were negatively associated with both factors (Table 5a). In 2007, percent C was positively correlated with seeded species cover and negatively correlated with non-seeded species cover. Nitrogen continued to be unrelated to cover of either seeded or non-seeded species. Seeded species were positively correlated and non-seeded species were negatively correlated with bareground. Seeded species were negatively correlated and non-seeded species were positively correlated with litter.

Table 5a. Statistics for simple linear regression of seeded and non-seeded species cover on percent C and N in 2006 (α=0.05).

Factor	Soil % Carbon			Soil % Nitrogen			Bareground			Litter		
	Coeff.	*P*	R^2	Coeff.	*P*	R^2	Coeff.	*P*	R^2	Coeff.	*P*	R^2
Seeded species cover	-0.60	0.45	0.01	-99.90	0.07	0.03	-0.10	0.07	0.03	-0.10	0.06	0.04
Non-seeded species cover	-5.4	0.01	0.07	-27.13	0.86	0.0003	-0.91	<0.0001	0.41	-0.78	<0.0001	0.30

Table 5b. Statistics for simple linear regression of seeded and non-seeded species cover on percent C and N in 2007 (α=0.05).

Factor	Soil % Carbon			Soil % Nitrogen			Bareground			Litter		
	Coeff.	*P*	R^2	Coeff.	*P*	R^2	Coeff.	*P*	R^2	Coeff.	*P*	R^2
Seeded species cover	3.61	0.009	0.07	73.68	0.46	0.006	0.56	0.0002	0.14	-0.19	0.01	0.07
Non-seeded species cover	-10.48	0.001	0.10	277.88	0.25	0.01	-2.03	<0.0001	0.32	0.79	<0.0001	0.21

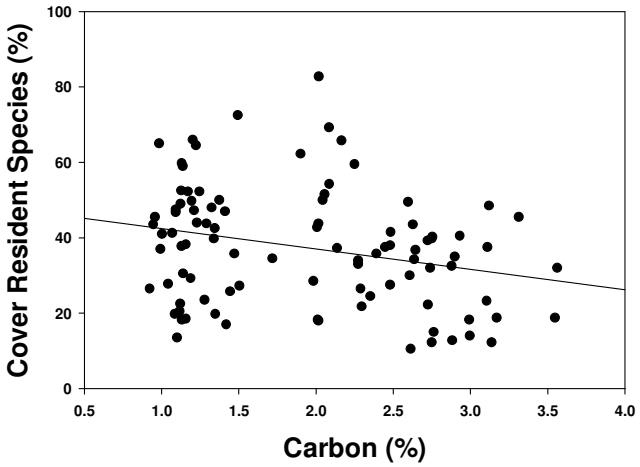


Figure 21. Simple linear regression of non-seeded species cover on soil percent C in 2006.

Animal activity

No burrowing mammal activity was observed in sampling plots or subplots in 2006. Elk scat was observed in two sampling plots and rabbit scat in a single plot. Grazing was noted on wild oat in one plot and western wheatgrass in another.

In 2007, rabbit scat was found in three plots, and a single animal burrow was found in another. Grazing of flower heads was noted on the abundant prickly lettuce in this year.

Species diversity

The overall diversity of the site showed an increase from 2006 to 2007. The seed mixes with the highest diversity for both years are Mix 3 and Mix 4. The diversity indices for seeded species and non-seeded species showed a slight increase in seeded species in 2007 compared to 2006 and a slight decrease in non-seeded species in 2007 compared to 2006. Simpson's index showed an increase in non-seeded native species diversity in 2007 and a slight decrease in non-seeded non-native species diversity. Shannon index shows very little change in diversity of non-

seeded native and non-seeded non-native species between 2006 and 2007. The results are summarized in Table 6a,b,c,d, Figure 21a,b, Figure 22, and Figure 23.

Table 6a. Species diversity indices for the entire site for 2006 and 2007.

Overall Diversity		
	2006	2007
Simpson's	4.07	6.17
Shannon	1.86	2.11

Table 6b. Species diversity indices by seed mix and year.

Diversity by Seed Mix	Mix 1		Mix 2		Mix 3		Mix 4	
	2006	2007	2006	2007	2006	2007	2006	2007
Simpson's	3.66	5.98	3.61	6.18	4.50	6.99	4.96	6.01
Shannon	1.73	2.09	1.78	2.09	1.99	2.22	1.97	2.05

Table 6c. Species diversity indices for seeded species and non-seeded species by year.

Seeded v Non-Seeded	Seeded		Non-Seeded	
	2006	2007	2006	2007
Simpson's	3.89	4.03	4.05	3.83
Shannon	1.33	1.37	1.38	1.36

Table 6d. Species diversity indices for non-seeded native and non-seeded non-native by year.

Non-Seeded Native v Non-Seeded Non-Native	Non-Seeded Native		Non-Seeded Non-Native	
	2006	2007	2006	2007
Simpson's	1.01	3.00	4.05	3.83
Shannon	1.31	1.27	1.38	1.36

Figure 21a. Species diversity by seed mix for 2006.

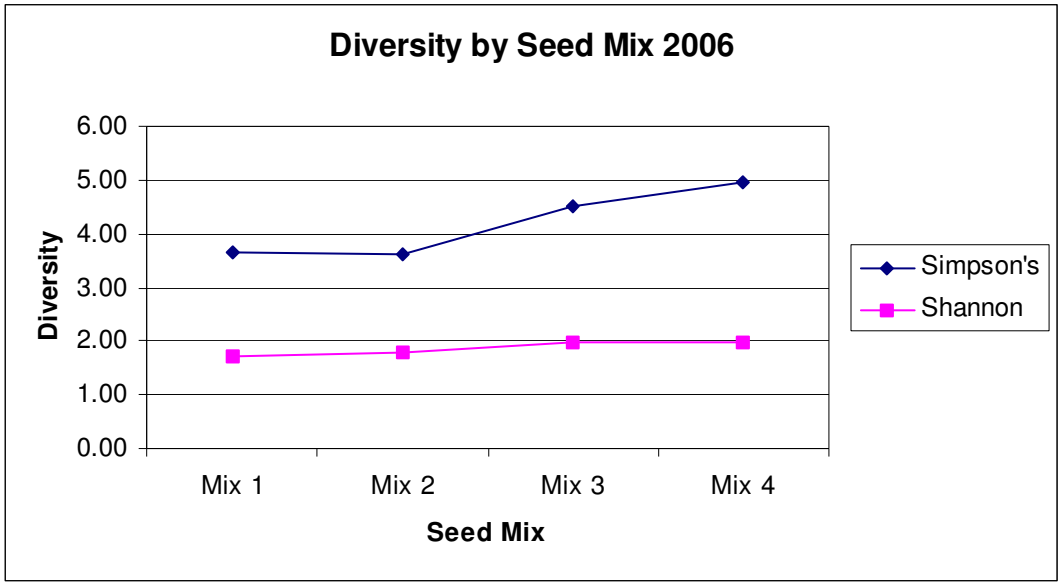


Figure 21b. Species diversity by seed mix for 2007.

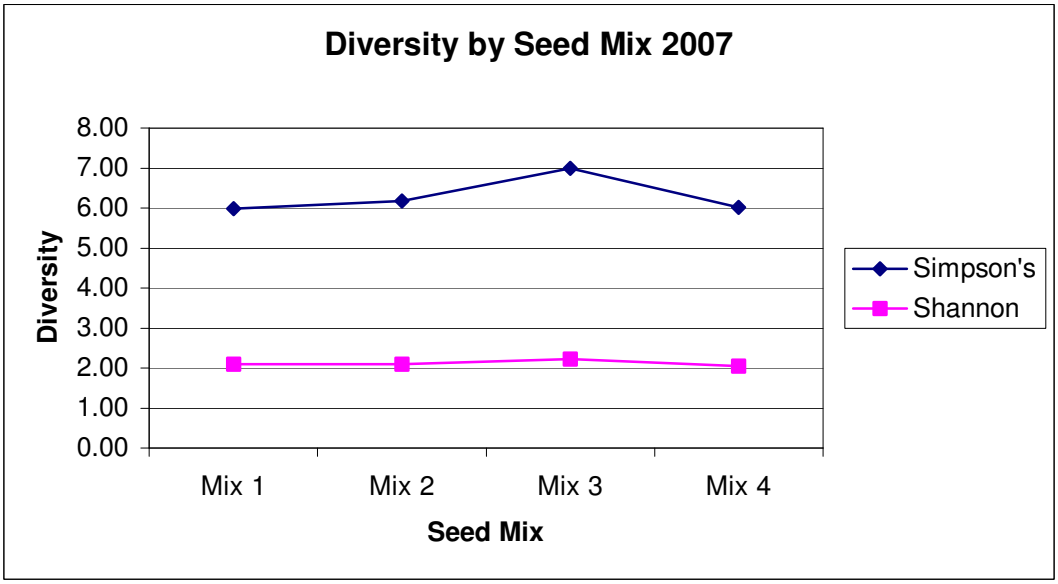


Figure 22. Species diversity for seeded and non-seeded species by year.

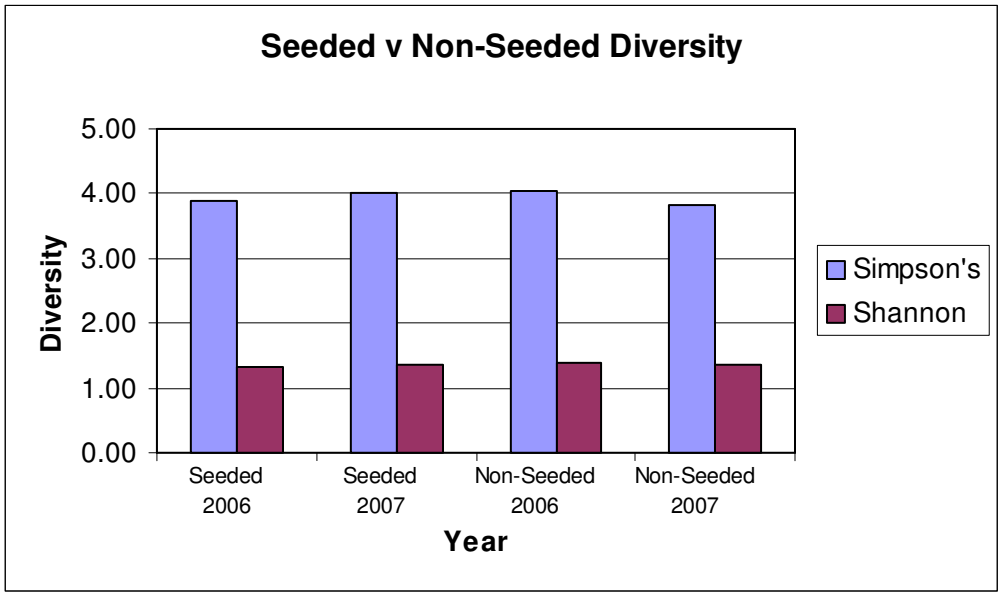
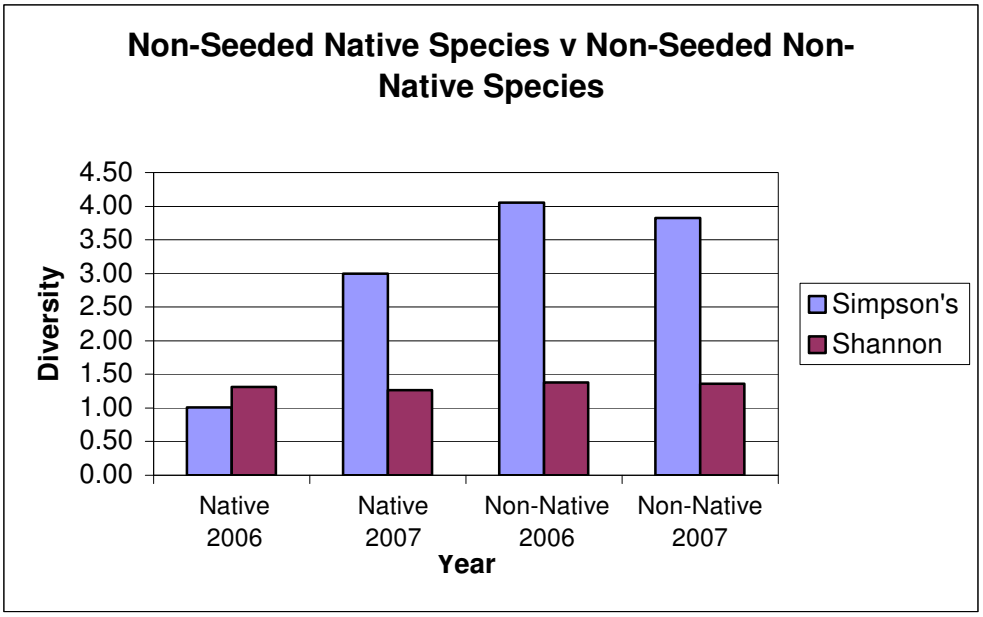


Figure 23. Species diversity for non-seeded native and non-seeded non-native species by year.



DISCUSSION OF RESULTS

Our results indicate that the cover of seeded species doubled in 2007. Our hypothesis that the abundance of seeded grasses, herbaceous forbs and shrubs would reflect their proportions in the seed mixtures was generally supported in the first year. Seeding proportion and density effects were observed in the first year after seeding for prairie plantings on agricultural lands in the Central Valley of California, but these differences were not apparent in subsequent years (Brown 1998). This same pattern appears to be emerging at this site as well.

We hypothesized that success of seeded species would be positively associated with low weed abundance. In the first year, there was no indication that non-seeded vegetation reduced the performance of seeded species. However, in 2007, there was a strong negative correlation between seeded and non-seeded species cover. This suggests that the non-seeded species may be having a significant negative effect on the seeded species in the second year of establishment.

We detected no relationship between the abiotic factors measured and establishment of seeded species in 2006. However, cover of non-seeded species decreased with increased soil percent C, bareground and litter. The decreased bareground with increased non-seeded species cover is a necessary reciprocal relationship. However, the decreased non-seeded species cover with increased litter may suggest suppression of germination. The patterns changed in 2007. In this second year, light interception by the canopy and cover of litter differed by location, and litter differed among seed mixture treatments. The most interesting shift that we detected was that although soil percent N continued to be unrelated to seeded or non-seeded species cover, soil percent C was strongly associated, in opposite directions. Non-seeded species continued to be negatively related to percent C, however, in 2007 percent C was positively associated with cover of seeded species, rather than not associated with it.

The reciprocal relationship between seeded and non-seeded species with percent soil C is of particular interest. Although higher C levels are usually associated with greater fertility, they may indicate lower N availability at our study site. We did not measure available N, but rather measured total N, which includes forms of N that are available to plants and those that are not. Early successional species flourish after resource-releasing disturbance, whereas perennial species are often less able to convert available nutrients into biomass as quickly due to slower growth rates (Claassen and Marler, 1998). The negative association between non-seeded species and soil C and the positive association between seeded species and soil C at our site may be indirectly due to lower N availability. The differences among blocks in soil C may be a legacy effect of the cultivation history of the site. This would seem to be supported by the fact that the site consists of only one soil type. We will investigate this further. It is important to determine

whether the characteristics of the soils, e.g. soil C, that favor seeded species and disfavor non-seeded species can be enhanced with management. We believe this is important to study further.

These results indicate that in the second year of the study, we are beginning to see plant community effects on and responses to these abiotic factors. We are observing the plant community develop and differences among treatments will lead to different inputs into ecosystem processes. Over time, we expect to see differences in ecosystem functions such as nutrient and water cycles. Although soil C levels were greater in blocks IV, V and VI, we detected no relationship between it and establishment of seeded species.

The performance of seeded species also seemed to be greatly affected by where in the field they were planted in both years. Which blocks resulted in greatest abundance of seeded species depended on the species. In 2006, overall performance of seeded species was best in Blocks II and III, on the north half of the field and farther away from the bottom of the drainage. Non-seeded species were also generally more abundant in this area in 2006. However, in 2007, the cover of seeded species appeared to be highest in Block VI, primarily due to greater cover of slender wheatgrass. Soil N did not differ across the field, thus, this measure of fertility does not appear to explain the observed differences. At this point no clear explanation for these differences has been identified.

Management implications

Increasing proportional representation of species in seed mixtures can lead to greater establishment in the first year after seeding. In particular, seed mixes 3 had a higher diversity compared to the other mixes both years. Location in the field influenced success of seeded species and learning more about the features and history of the different areas will assist in

making the best species selections. The reasons for the underlying differences in soil C should be identified to determine whether this characteristic can be manipulated through management activities to favor desired species. It appears that seeding diverse mixtures of species can maximize the likelihood that species adapted to the different microenvironments on a site will be present. This may lead to establishment of different species in different microsites, and good establishment overall.

The methods of seed bed preparation and seeding were quite effective under the climatic conditions of 2005- 06. It is still very early in the development of the seeded species to reach any final conclusions. Continued monitoring will be important in order to assess the long-term success of this restoration project.

We suggest testing multiple control methods for managing non-native species while the seeded species are becoming established including, but not limited to: (1) application of broadleaf specific herbicides to grass only plots, (2) testing the efficacy of carbohydrate starvation for Canada thistle and field bindweed management, (3) selective mowing to reduce kochia competition and seed production, and (4) release of biological control agents for the control of field bindweed. We also encourage BCPOS to utilize the CEMEX Study Site to its greatest benefit by continuing to facilitate long term research on native and non-native species and their interactions with each other and the environment.

CONCLUSION

The establishment of seeded species on this site has been very successful. Many of the species that have not been apparent initially may become established in later years. This is especially likely for forb and shrub species, which are known to have long-lived seed and high

levels of dormancy. For the future, the project will provide the opportunity for long term research, testing establishment and management methods including, but not limited to: (1) staged revegetation and restoration approaches by introducing forbs after native grass establishment, enabling the use of broadleaf-specific herbicides until then (Brown and Bugg 2001), (2) comparison of efficacy of seeding vs. transplanting shrubs in sequential introduction, (3) testing methods of weed control and resource manipulation to facilitate the establishment of a diverse native plant community, (4) studying ability of native plants to compete with weedy species and the impact that weedy species have on native species (Dukes 2001), and (5) assessing the soil seed bank to evaluate the relative abundance of seeded forbs, which are a highly desired part of the plant community, but remain less common in the aboveground plant community than grasses.

ACKNOWLEDGEMENTS

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Appendix 1. Monocultures

Rep 1 I-II N to S	Replicate b/wn blocks I-II Common name	Rep 2 II-III N to S	Replicate b/wn blocks II-III Common name	Rep 3 IV-V N to S	Replicate b/wn blocks IV-V Common name	Rep 4 V-VI N to S	Replicate b/wn blocks V-VI Common name
1	Blanketflower	1	Rabbitbrush (Rubber)	1	Buffalograss	1	Green Needlegrass
2	Indian Ricegrass	2	Little Bluestem	2	Purple prairie clover	2	Scarlet Globemallow
3	Fourwing Saltbush	3	Western Wheatgrass "Arriba"	3	Slender Wheatgrass	3	Indian Ricegrass
4	Fringed Sage	4	Buffalograss	4	Yellow Coneflower	4	Side Oats Grama
5	Yellow Coneflower	5	Green Needlegrass	5	Prairie Sage	5	Purple prairie clover
6	Little Bluestem	6	Scarlet Globemallow	6	Blue Grama	6	Buffalograss
7	Buffalograss	7	Side Oats Grama	7	Scarlet Globemallow	7	Blue Grama
8	Purple prairie clover	8	Yellow Coneflower	8	Indian Ricegrass	8	Rabbitbrush (Rubber)
9	Junegrass	9	Indian Ricegrass	9	Blanketflower	9	Little Bluestem
10	Scarlet Globemallow	10	Fourwing Saltbush	10	Western Wheatgrass "Native"	10	Fringed Sage
11	Side Oats Grama	11	Purple prairie clover	11	Side Oats Grama	11	Prairie Sage
12	Prairie Sage	12	Fringed Sage	12	Green Needlegrass	12	Slender Wheatgrass
13	Blue Grama	13	Slender Wheatgrass	13	Little Bluestem	13	Junegrass
14	Green Needlegrass	14	Blue Grama	14	Junegrass	14	Western Wheatgrass "Arriba"
15	Western Wheatgrass "Arriba"	15	Blanketflower	15	Western Wheatgrass "Arriba"	15	Western Wheatgrass "Native"
16	Western Wheatgrass "Native"	16	Junegrass	16	Fourwing Saltbush	16	Yellow Coneflower
17	Rabbitbrush (Rubber)	17	Prairie Sage	17	Rabbitbrush (Rubber)	17	Fourwing Saltbush
18	Slender Wheatgrass	18	Western Wheatgrass "Native"	18	Fringed Sage	18	Blanketflower

Appendix 2. Seed mixtures

Mix 1

Common Name *Species* "Variety"	Approx. Seeds/#	% of Mix	# PLS/ft2	PLS#/Acre	Comments
Side Oats Grama *Bouteloua curtipendula* "Vaughn"	191000	5.5	50	0.63	
Blue Grama *Bouteloua gracilis* Native	825000	7.5	50	0.20	
Buffalograss *Buchloe dactyloides* "Texoka"	56000	6	50	2.33	
Slender Wheatgrass *Elymus trachycaulus* "San Luis"	159000	5	50	0.68	
Junegrass *Koeleria macrantha* Native	2315400	5	50	0.05	
Western Wheatgrass *Pascopyrum smithii* "Arriba"	110000	2.5	50	0.50	
Western Wheatgrass *Pascopyrum smithii* Native	110000	2.5	50	0.50	
Indian Ricegrass *Oryzopsis hymenoides* "Rimrock"	141000	5	50	0.77	
Little Bluestem *Schizachyrium scoparium* "Camper"	260000	6	50	0.50	
Green Needlegrass *Stipa viridula* "Lodorm"	181000	5	50	0.60	
Total Grasses		**50**		**6.8**	

Forbs & Shrubs

Prairie Sage *Artemisia ludoviciana*	4500000	5	50	0.0242	1 oz = 0.0625, Ast
Fringed Sage *Artemisia frigida*	4536000	5	50	0.0240	Ast
Fourwing Saltbush *Atriplex canescens*	52000	5	50	2.09	Chn
Rabbitbrush (Rubber) *Chrysothamnus nauseosus*	400000	6	50	0.33	Ast
Purple prairie clover, Kanab *Dalea purpurea*	300000	9	50	0.65	Fab
Blanketflower *Gaillardia arstita*	199999	4.5	50	0.49	
Yellow Coneflower *Ratibida columnifera*	1230000	9	50	0.16	Ast
Scarlet Globemallow *Sphaeralcea coccinea*	500000	6.5	50	0.28	Mal
Total Forbs & Shrubs		**50**		**4.1**	

Mix 2

Common Name *Species* "Variety"	Approx. Seeds/#	% of Mix	# PLS/ft2	PLS#/Acre	Comments
Side Oats Grama *Bouteloua curtipendula* "Vaughn"	191000	8.25	50	0.94	
Blue Grama *Bouteloua gracilis* Native	825000	11.25	50	0.30	
Buffalograss *Buchloe dactyloides* "Texoka"	56000	9	50	3.50	

Slender Wheatgrass *Elymus trachycaulus* "San Luis"	159000	7.5	50	1.03	
Junegrass *Koeleria macrantha* Native	2315400	7.5	50	0.07	
Western Wheatgrass *Pascopyrum smithii* "Arriba"	110000	3.75	50	0.74	
Western Wheatgrass *Pascopyrum smithii* Native	110000	3.75	50	0.74	
Indian Ricegrass *Oryzopsis hymenoides* "Rimrock"	141000	7.5	50	1.16	
Little Bluestem *Schizachyrium scoparium* "Camper"	260000	9	50	0.75	
Green Needlegrass *Stipa viridula* "Lodorm"	181000	7.5	50	0.90	
Total Grasses		**75**		**10.1**	Grain seed box
<u>Forbs & Shrubs</u>					
Prairie Sage *Artemisia ludoviciana*	4500000	2.5	50	0.0121	1 oz = 0.0625 Ast
Fringed Sage *Artemisia frigida*	4536000	2.5	50	0.0120	Ast
Fourwing Saltbush *Atriplex canescens*	52000	2.5	50	1.05	Chn
Rabbitbrush (Rubber) *Chrysothamnus nauseosus*	400000	3	50	0.16	Ast
Purple prairie clover *Dalea purpurea*	300000	4.5	50	0.33	Fab
Blanketflower *Gaillardia arstita*	199999	2.25	50	0.25	

Yellow Coneflower *Ratibida columnifera*	1230000	4.5	50	0.08	Ast
Scarlet Globemallow *Sphaeralcea coccinea*	500000	3.25	50	0.14	Mal
Total Forbs & Shrubs		**25**		**2.0**	Fluffy seed box

Mix 3

Common Name *Species* "Variety"	Approx. Seeds/#	% of Mix	# PLS/ft2	PLS#/Acre	12 Acres	Comments
Side Oats Grama *Bouteloua curtipendula* "Vaughn"	191000	8	50	0.91	10.95	
Blue Grama *Bouteloua gracilis* Native	825000	9.7	50	0.26	3.07	
Buffalograss *Buchloe dactyloides* "Texoka"	56000	8	50	3.11	37.34	
Slender Wheatgrass *Elymus trachycaulus* "San Luis"	159000	6.6	50	0.90	10.85	
Junegrass *Koeleria macrantha* Native	2315400	6.6	50	0.06	0.75	
Western Wheatgrass *Pascopyrum smithii* "Arriba"	110000	3.1	50	0.61	7.37	
Western Wheatgrass *Pascopyrum smithii* Native	110000	3.1	50	0.61	7.37	
Indian Ricegrass *Oryzopsis hymenoides* "Rimrock"	141000	6.6	50	1.02	12.23	
Little Bluestem *Schizachyrium scoparium*	260000	8	50	0.67	8.04	

"Camper"						
Green Needlegrass *Stipa viridula* "Lodorm"	181000	6.6	50	0.79	9.53	
Total Grasses		**66.3**		**9.0**	**107.49**	Grain seed box
Forbs & Shrubs						
Prairie Sage *Artemisia ludoviciana*	4500000	3.3	50	0.0160	0.19	1 oz = 0.0625 Ast
Fringed Sage *Artemisia frigida*	4536000	3.3	50	0.0158	0.19	Ast
Fourwing Saltbush *Atriplex canescens*	52000	3.3	50	1.38	16.59	Chn
Rabbitbrush (Rubber) *Chrysothamnus nauseosus*	400000	4	50	0.22	2.61	Ast
Purple prairie clover, Kanab *Dalea purpurea*	300000	6	50	0.44	5.23	Fab
Blanketflower *Gaillardia arstita*	199999	3	50	0.33	3.92	Ast
Yellow Coneflower *Ratibida columnifera*	1230000	6	50	0.11	1.27	Ast
Scarlet Globemallow *Sphaeralcea coccinea*	500000	4.3	50	0.19	2.25	Mal
Total Forbs & Shrubs		**33.2**		**2.7**	**32.3**	

Mix 4

Common Name *Species* "Variety"	Approx. Seeds/#	% of Mix	# PLS/ft2	PLS#/Acre
Side Oats Grama *Bouteloua curtipendula* "Vaughn"	191000	10.5	50	1.20
Blue Grama	825000	15	50	0.40

Bouteloua gracilis Native				
Buffalograss *Buchloe dactyloides* "Texoka"	56000	12	50	4.67
Slender Wheatgrass *Elymus trachycaulus* "San Luis"	159000	10	50	1.37
Junegrass *Koeleria macrantha* Native	2315400	10	50	0.09
Western Wheatgrass *Pascopyrum smithii* "Arriba"	110000	5.25	50	1.04
Western Wheatgrass *Pascopyrum smithii* Native	110000	5.25	50	1.04
Indian Ricegrass *Oryzopsis hymenoides* "Rimrock"	141000	10	50	1.54
Little Bluestem *Schizachyrium scoparium* "Camper"	260000	12	50	1.01
Green Needlegrass *Stipa viridula* "Lodorm"	181000	10	50	1.20
Total Grasses		**100**		**13.6**