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PLANT MATERIALS TECHNICAL NOTE

Establishing Winterfat and Forage Kochia on Four Seedbed Treatments in Cheatgrass or Crested Wheatgrass Dominated Sites

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Figure 1. Winterfat establishment in cheatgrass two years after seeding

Summary

Winterfat (*Krascheninnikovia lanata*), a North American native, and forage kochia (*Bassia prostrata*), native to Eurasia, share a similar ecological niche and serve similar conservation and nutritional functions. Our objective was to quantify the establishment of these two species broadcast seeded onto four seedbed preparation treatments (1-none, 2-harrow, 3-disk, and 4-disk-seed-then-roll) at three sites in south-central Montana. Site 1 was established in 2011 during above normal early season precipitation on a disturbed area with cheatgrass (*Bromus tectorum*) grading to native western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*) rangeland. Sites 2 and 3 were established in 2012 during below normal growing season precipitation on well established crested wheatgrass (*Agropyron cristatum*) pastures. Establishment of both species was poor to nil on the no seedbed and harrow treatments, was improved slightly on the disked plots, and significantly greater where the seedbed was disked-seeded- and rolled. The results demonstrate the importance of good seed to soil contact for the establishment of conservation seedings. If winterfat and forage kochia persist, disking followed by broadcast seeding and rolling seeds of these species and others with similar seed ecology (like big

sagebrush-*Artemisia tridentata*) is a method to improve species diversity, wildlife habitat, and late season forage quality on sites dominated by cheatgrass or crested wheatgrass.

Introduction

The Bridger Plant Materials Center (PMC) 2012 – 2017 Long Range Plan lists developing and testing minimum till techniques for establishment of saline-tolerant species, establishing and evaluating forage species for management of invasive plants, and evaluating shrub species that retain high forage quality into the winter as actions to address pasture conservation needs. To this end, three field plantings were established in south-central Montana testing seedbed preparation methods for the establishment of winterfat or forage kochia. The three cooperating landowners had the same objective, to improve late-season forage quality for either sheep or cattle. None of the three sites have high salinity soils, but both winterfat and forage kochia have moderate to high salinity tolerance. One field planting site had a heavy infestation of cheatgtrass and the other two were in crested wheatgrass.

Figure 2. Forage kochia growing in cheatgrass at Site 1

Winterfat (see Figure 1) is native to the 7- to 16-inch annual precipitation zones in western North America (Ogle et al., 2012). Forage kochia (see Figure 2) is native to similar precipitation zones in Central Asia (Harrison et al., 2000; Tilley et al., 2012). Both species are in the Amaranthaceae (formerly Chenopodeaceae) taxonomic family. They maintain high forage quality for livestock and wildlife into fall and winter, and re-sprout after grazing and fire. Both are listed in floras as sub-shrubs or half shrubs, but this may be a function of grazing pressure. We have observed winterfat shrubs similar in size to big sagebrush (*Artemisia tridentata*) when they have not been grazed.

Both species tolerate high salinity soils. They grow taproots capable of penetrating deeply into the soil and have extensive shallow fibrous root systems. Their seeds are fast-establishing utricles with well-developed embryos but have short viability of less than two years. For establishment, both species can be broadcast seeded in late fall, winter or early spring directly onto snow or the soil surface. The recommendation for forage kochia includes broadcasting onto soil that has been lightly disturbed by harrowing (Tilley et al., 2012). Winterfat maintains protein content into the winter and is a valued conservation plant for restoring wildlife habitat and stabilizing soil on disturbed sites in Montana and Wyoming. Forage kochia has gained attention for restoration of cheatgrass sites in the Great Basin of North America and for its late-season forage quality for livestock. It is reported to be non-invasive in North America, but in Montana it is relatively untested.

Cheatgrass is an invasive annual grass from the Mediterranean region (Menalled et al., 2008). In Montana and Wyoming, its invasion is facilitated by summer drought, heavy grazing and other disturbances. Where large-scale populations form near mono-specific stands, forage quality and quantity are reduced, particularly in the summer months and during dry falls and winter, reducing livestock carrying capacity and wildlife habitat. Restoring forage plants into cheatgrass dominated stands has proven difficult.

Crested wheatgrass is a long-lived perennial grass introduced from Asia and commonly seeded in the arid and semi-arid western North America (Ogle, 2006). Crested wheatgrass pastures provide good spring forage for all classes of livestock and wildlife, however forage quality declines in the summer and, when late season soil moisture is limited, remains low throughout the fall and winter. Where seeded, it forms near mono-specific stands with low forb and shrub diversity important to some wildlife species. Restoring species diversity to crested wheatgrass stands has also proven difficult.

Our objectives were to measure establishment and persistence of winterfat and forage kochia after their seeds were broadcast onto four seedbed preparation treatments; no seedbed preparation (none), harrowing, disking, and disking-seeding- then rolling (disk-roll). Our hypothesis is establishment and persistence of both species will be greatest where seeds are broadcast onto a disked seedbed then rolled for good seed to soil contact, greater on the disked seedbed then the harrowed seedbed, and lowest on no seedbed preparation.

Methods

Site Descriptions

We tested winterfat and forage kochia establishment on three sites in south-central Montana. Site 1 was established in the spring of 2011 which had well-above normal spring and early summer precipitation followed by a hot, dry late summer and fall. Sites 2 and 3 were established in the spring of 2012 which experienced among the driest and hottest springs and summers on record. Neither winterfat nor forage kochia were present on the sites at the time of field planting establishment. Soils were not tested for nutrients before the plantings.

Figure 3. Field planting Site 1

Site 1 (see Figure 3) is located in Stillwater County, Montana (45.71778 N, -108.97952 W). The ecological site description is Silty, Major Land Resource Area (MLRA) 58A, 11 to 14 inch precipitation zone. The elevation is 3,850 feet. The soil is Lambeth-Yawdim complex silt loam with a pH of 8.2, salinity range of 0 to 3.0 millimhos per centimeter, sodium adsorption ratio of 0, and an average 5% slope across the site. The site was not irrigated. The land owners raised Icelandic sheep and were interested in improving winter season forage quality near their lambing and doctoring pens. They selected an area east of the pens for the study. The three replications were blocked by disturbance. The first replication next to the pens where bedding straw and manure was stockpiled had the greatest disturbance and was dominated by cheatgrass. Replications 2 and 3 to the east were relatively undisturbed western wheatgrass, needle and thread plant community with cheatgrass. The straw and manure were scraped off replication 1 before the seedbed preparation treatments were applied.

Site 2 is in Carbon County (45.16819 N, -108.69158 W) on a well-established crested wheatgrass pasture corner next to a pivot irrigation system. The ecological site description is Silty-Limey, MLRA 46, 10- to 14-inch precipitation zone. The site received no supplemental water. The soils are Stormitt loam with gravelly loam texture. Stormitt soils have a pH range of 7.9 to 8.4, salinity range of 0 to 2.0 millimhos per centimeter, a sodium adsorption ratio of 0, and the percent organic matter in the upper 6 inches is 1.0 to 2.0. The elevation is 4,720 feet, the average annual precipitation is

13 inches, and the site slopes slightly (4%) to the west. Vegetation composition is 75% crested wheatgrass, 15% fringed sage (*Artemisia frigida*), 5% broom snakeweed (Gutierrezia sarothrae) and 5% alfalfa (*Medicago sativa*). The land owner is interested in improving forage diversity and quality for a cattle operation.

Site 3 is also on a well established crested wheatgrass pasture with no supplemental water in Carbon County (45.4404 N, -108.69158 W), but on an Absarokee clay loam soil. The ecological site description is Clayey, MLRA 46, 13- to 19-inch precipitation zone. Absarokee soils have a pH range of 6.1 to 7.3 in the upper 3 inches and 6.6 to 8.4 down to 35 inches. Salinity ranges from 0 to 2.0 millimhos per centimeter, the sodium adsorption ration is 0, and the percent organic matter ranges from 3.0 to 6.0 in the upper 3 inches and 1.0 to 2.0 down to 50 inches. The elevation is 4,600 feet, the average annual precipitation is 17 inches, and the site slopes slightly (4%) to the west. Vegetation composition is 80% crested wheatgrass, 10% needle and thread, and 5% fringed sage, and 5% cheatgrass. Though under different ownership, the land owner objectives are the same as those of Site 2.

Experimental Design

Each field planting site was first divided into three replications to allow statistical evaluation using analysis of variance (ANOVA). Each replication was equally divided into four randomly arranged seedbed treatments representing three levels of disturbance; no treatment, harrow, disk, and disk-roll. Each seedbed treatment was split equally into three randomly arranged species seeded treatments, no seeding, seeding winterfat, or seeding forage kochia. This combined all species seeded treatments with all seedbed treatments randomly applied within each of the three replications for a randomized split-plot experimental design. The design allows testing the effect of seedbed treatment on establishment, if the species establish differently, if a seedbed treatment effect depends on the species seeded, if the species establish without seed inputs (not likely with forage kochia, but possible with winterfat), and over time, if the species invade into plots with no artificial seeding.

Each site was prepared by the cooperating land owner. Site 1 (Bales) measured 350 by 200 feet (1.6 acres), each seedbed treatment was 117 by 50 feet, and each seeding treatment was 117 by 17 feet. Seedbed treatments were applied on 1 April 2011. A spring-tooth harrow was dragged lengthwise up and down the plots for the harrow treatment (see Figure 4B). Similarly, in the disked plots, an off-set tandem disk was dragged lengthwise up and down the plots turning the soil to a depth of about 4 inches (see Figure 4 C and D). Winterfat seed was de-fluffed at the Bridger Plant Materials Center (PMC), mixed with 0.5 pounds of rice hulls to facilitate even distribution, and broadcast into the designated plots at 2.5 pounds pure live seed (PLS) per acre. 'Immigrant' forage kochia seed was mixed with 0.5 pounds of rice hulls and seeded into designated plots at 1.5 pounds PLS per acre. Plots were seeded on 4 April 2011 in a stiff cross wind (southeasterly). Plots receiving the disk-roll treatment were rolled immediately after seeding. A storm moved in and the plots were covered with snow by the next morning.

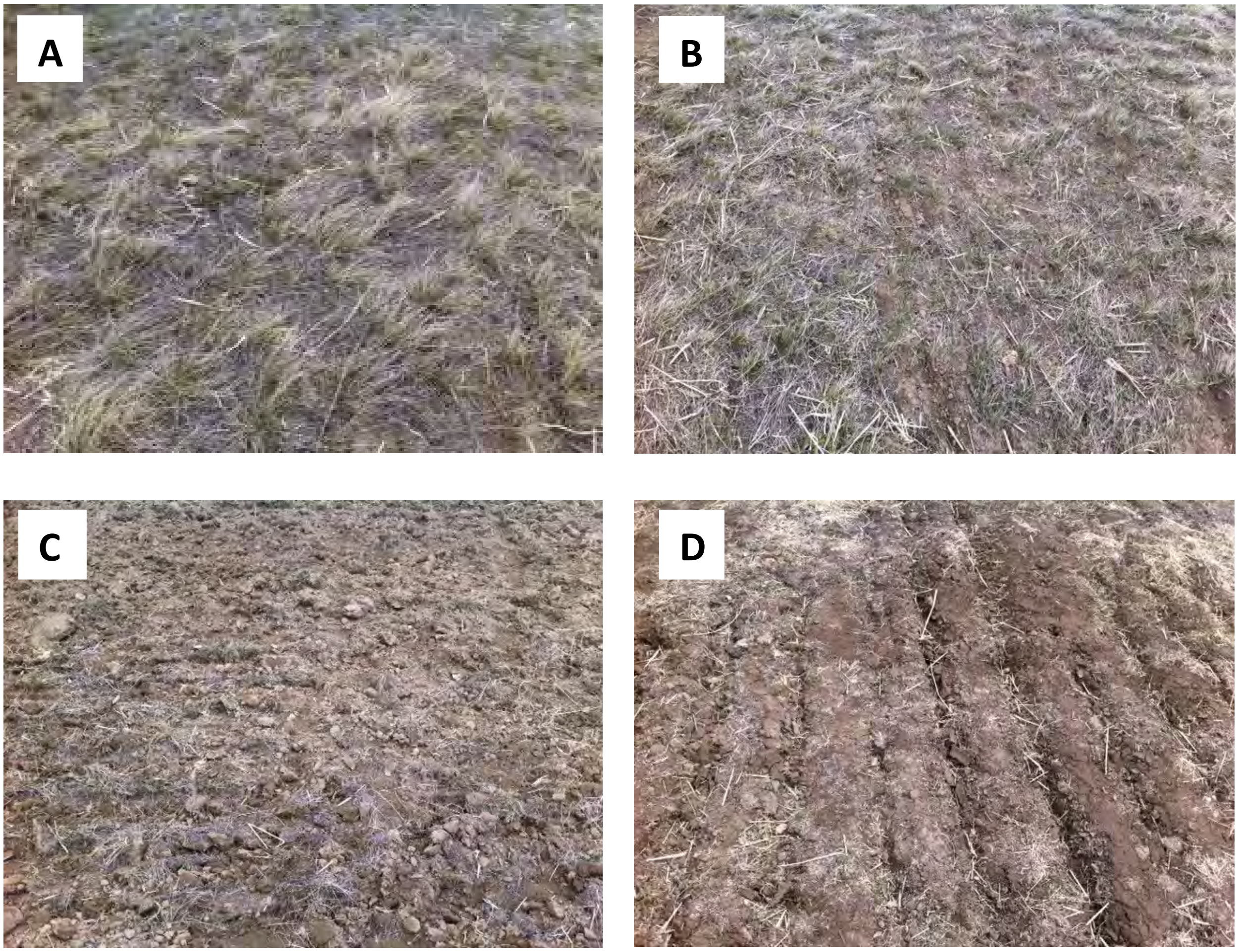

Figure 4. Seedbed treatments at Site 1: A - no seedbed preparation treatment, B – harrow seedbed treatment, C – disk seedbed treatment, and D – disk and roll seedbed treatment.

Site 2 (Murray) measured 360 by 250 feet (2 acres), each seedbed treatment was 120 by 63 feet, and each seeding treatment was 120 by 21 feet. Seedbed and seeding treatments were applied 27 March 2012 similarly to Site 1 except the equipment used was heavier resulting in a disking depth of about 10 inches. Follow this link to view the disked seedbed preparation at Site 2: http://www.youtube.com/watch?v=4oP4-cITZgQ. Similar to Site 1, winterfat seeds were de-fluffed at the Bridger PMC, mixed with 0.5 pounds of rice hulls, but were seeded at 1.8 pounds PLS per acre. Forage kochia seeds were mixed with 0.5 pounds of rice hulls and broadcast at 0.9 pounds PLS per acre.

Site 3 (Paugh) measured 270 by 120 feet (0.7 acres), each seedbed treatment was 90 by 40 feet, and each seeding treatment was 90 by 13 feet. Seedbed treatments and seeding were applied 28 March 2012 similarly to Site 2, except the disked treatments used lighter equipment than Site 2 and only tilled about 6 inches deep. Follow this link to view the disked seedbed preparation at Site 3: http://www.youtube.com/watch?v=21J3m2x5Tao.

All three sites were fenced after seeding to prevent livestock grazing.

Evaluations

The establishment of winterfat and forage kochia were measured by pacing one random transect lengthwise in the middle of each plot and counting the number of seedlings within ten 4.8 square foot hoops placed at approximately every three paces. This provides an average density for the plot and a frequency of occurrence (percentage) calculation to estimate evenness of stand. Site 1 was evaluated 1 September 2011 and 28 August 2012, Site 2 was evaluated 29 August 2012, and Site 3 was evaluated 29 August 2012. Data were analyzed using a split-plot ANOVA model (see Appendix A for ANOVA details). Because Site 1 had two years of data, the plant community was different, and the seeding rates were different than Sites 2 and 3; it was analyzed separately. Data from Sites 2 and 3 had similar variances and were combined for their analysis, however the no seedbed and harrow treatments were removed from the analysis because neither winterfat nor forage kochia seedlings were found in these plots.

Figure 5. First-year forage kochia (left) and winterfat (right) seedling in the disk-roll seedbed treatment at the time of evaluation on Site 2.

Results

Site 1

At all three sites, first-year winterfat and forage kochia seedlings were generally six inches tall or less (see Figure 5). The exception was the first replication at Site 1 where straw and manure from lambing and doctoring pens was piled and some first year seedlings exceeded six inches at the time of sampling. The two seedbed treatments in this replication most impacted by this disturbance were the disk and roll and the no seedbed treatment. The ANOVA for both density and frequency data indicate there was no difference ($p>0.5$, Appendix A) in establishment and evenness of establishment caused by differences in the replications. What was striking in the first replication was the amount of growth of both species observed one month after evaluation in both 2011 and 2012. This is particularly interesting considering the drought conditions at the end of 2011 and throughout 2012, and the density of competing cheatgrass in this replication. This indicates the potential elevated nutrients in replication 1 resulted in larger plants but did not influence the density or frequency of establishment.

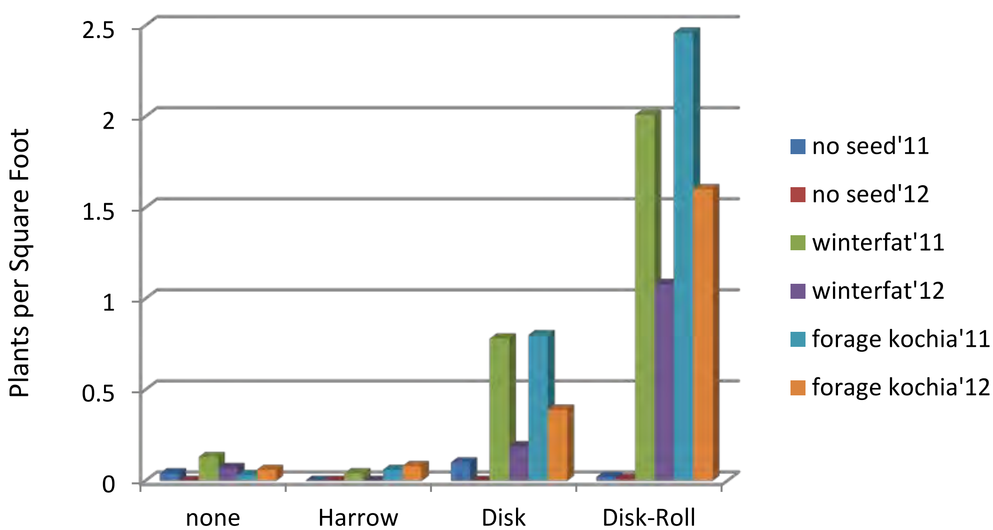

Figure 6. The Site 1 average of three replications for densities in 2011 and 2012 of winterfat and forage kochia seeded into seedbeds with no preparation (none), harrowed, disked, or disk-roll.

The average densities of winterfat and forage kochia within each seedbed treatment for the first two establishment years at Site 1 are shown in Figure 6. A few seedlings were counted in plots where no seed was broadcast, but it is likely these seedlings sprouted from seed blown onto the plots from neighboring plots during broadcasting and not from seed produced on the plots. Densities on the no seedbed treatment, harrowed plots, and where no seed was broadcast was low, disking improved establishment, and rolling after broadcasting on disked plots greatly increased establishment where seed was broadcast.

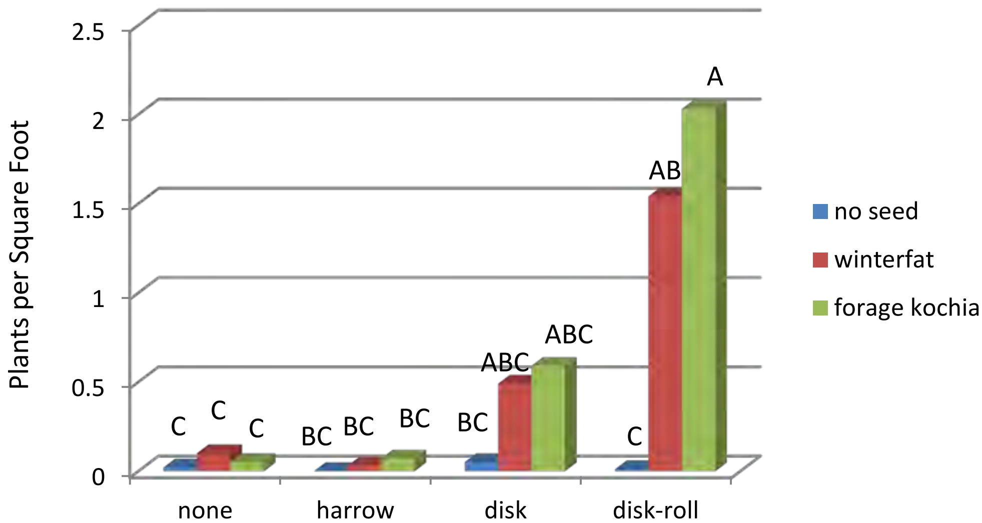

Figure 7. The mean densities of winterfat and forage kochia in seedbed treatments on Site 1 for 2011 and 2012 combined. Different letters above the bars indicate statistical differences among means determined by ANOVA and Tukey HSD all-pairwise test for the treatment by species interaction.

The ANOVA of Site 1 data found the effect of seedbed treatment on densities depended on the species seeded (P=0.0178, Appendix A). Winterfat establishment was not statistically different than forage kochia establishment within each of the seedbed treatments and their densities were only statistically greater than where there were no seed inputs in the disk-roll seedbed treatment (Figure 7). Forage kochia density in the disk-roll seedbed treatment was statistically greater than all densities in the harrow seedbed treatment, where there was no seedbed treatment, and in the disk seedbed treatment with no seed inputs. Winterfat density in the disk-roll treatment was only statistically greater than all densities in the no seedbed treatment. From the analysis we conclude; 1) both species need a disturbance more severe than our harrow treatment to reliably establish, 2) establishment of both species when broadcast onto a disked seedbed is no different than no seed inputs if there is not a seed-to-soil contact treatment like rolling, 3) it is unlikely either species is invasive on this site without a significant disturbance.

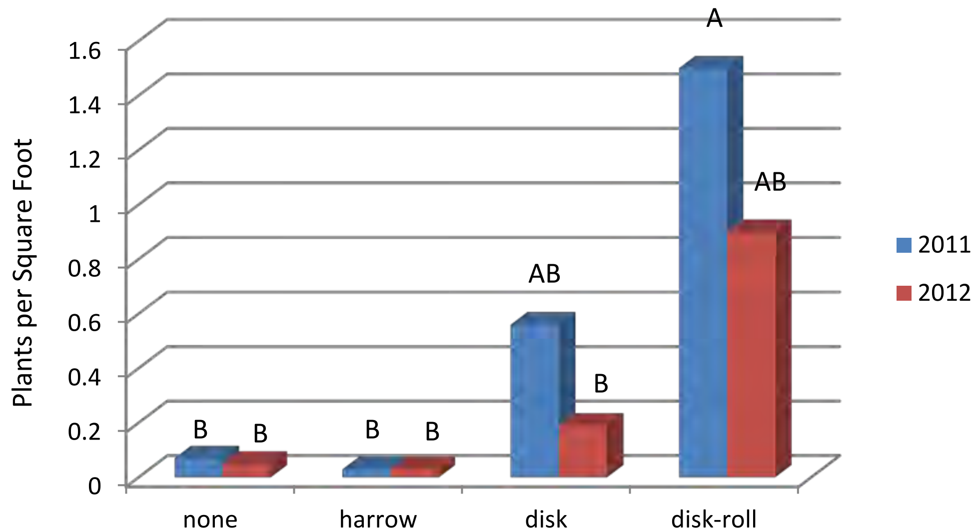

Figure 8. The mean densities (from the winterfat, forage kochia, and no seeding subplots combined) in the seedbed treatments in 2011 and 2012 at Site 1. Different letters above the bars indicate statistical differences among means determined by ANOVA and Tukey HSD all-pairwise test for the treatment by year interaction.

The ANOVA of Site 1 data found the effect of seedbed treatment on density depended on the sample year (0.0438, Appendix A). This interaction is depicted in Figure 8. It shows densities from 2011 to 2012 within seedbed treatments were not statistically different, but 2011 density in the disk-roll treatment was greater than densities in the none and harrow seedbed treatments, and 2012 density in the disk treatment. We believe this result is a function of the roughness of the un-smoothed disked seedbed treatment and the broadcast seeding. In 2011 where the seedbed was disked, establishment ranged from 0 to 55 seedlings per square foot. It is common when broadcasting for seedlings to establish in clumps, and this effect is more pronounced when the seedbed is not smoothed by a packing treatment. An advantage of drill seeding over broadcast seeding is even distribution of seeds. This is best accomplished when drill seeding on a smooth, firm seedbed. In 2012, densities where the seedbed had been disked ranged from 0 to 26 seedlings per square foot. Most of the declines in seedlings from 2011 to 2012 were in plots that were disked and had high initial seedling densities.

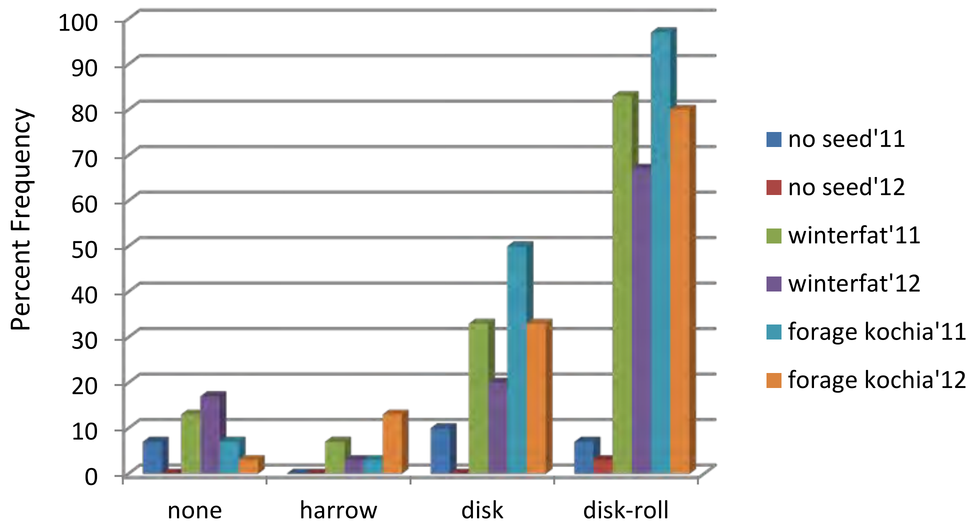

Figure 9. The mean frequencies of winterfat and forage kochia in 2011 and 2012 in each of the four seedbed treatments showing the non-significant declining trend in frequencies over time.

We use the average percent of winterfat and forage kochia found in the ten sample plots as a measure of frequency of occurrence to indicate how evenly seedlings established in the plots. Frequencies of occurrence within each seedbed treatment for the first two establishment years at Site 1 are shown in Figure 9. The ANOVA found that frequency declined from 26% in 2011 to 20% in 2012 (*P*=0.0192, Appendix A) and this effect was not dependent on the seedbed treatment or the species seeded.

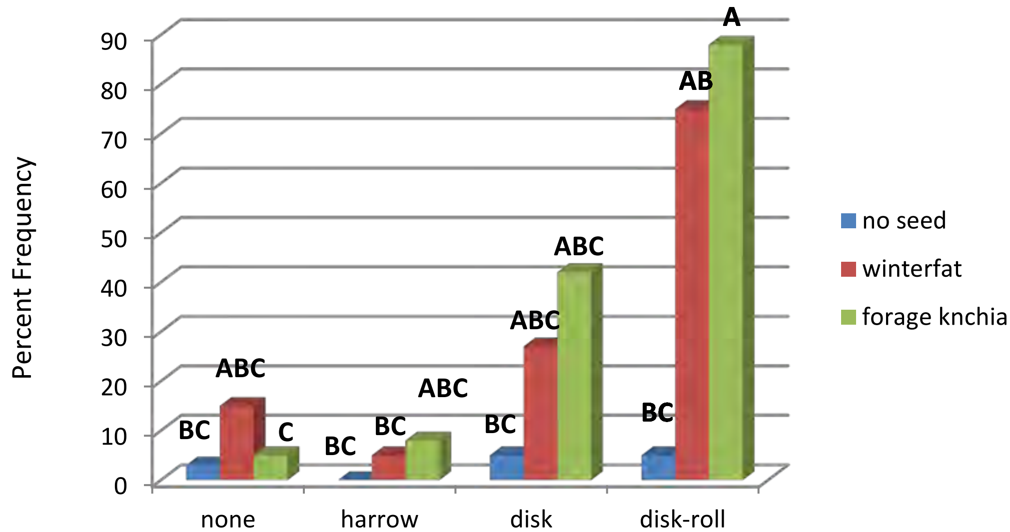

Figure 10. The interaction effect of seedbed treatment and species seeded on the mean frequencies of occurrence of winterfat and forage kochia at Site 1. Different letters above the bars indicate statistical differences among means determined by ANOVA and Tukey HSD all-pairwise test for the treatment by year interaction (α=0.05).

The ANOVA also found the effect of seedbed treatment on frequency depended on the species seeded (P=0.0129, Appendix A). This interaction is shown in Figure 10. Forage kochia was found in 88% of the disk-roll plots where it was seeded, but this was only significantly greater than no seeding in all seedbed treatment plots, the harrow plots where winterfat was seeded, and the no seedbed treatment plots where forage kochia was seeded. Winterfat was found in 75% of the disk-rolled plots where it was seeded, but was only significantly more frequent than the no seedbed treatment where forage kochia was seeded. From the analysis we conclude: 1) rolling to improve seed-to-soil contact after a disking seedbed treatment and broadcast seeding improves establishment evenness of winterfat and forage kochia, at least in some circumstances, 2) the establishment evenness overall on the site was highly variable as might be expected with a broadcast seeding, 3) the reduction in frequency from 2011 to 2012 was not affected by species or seedbed treatment.

Sites 2 and 3

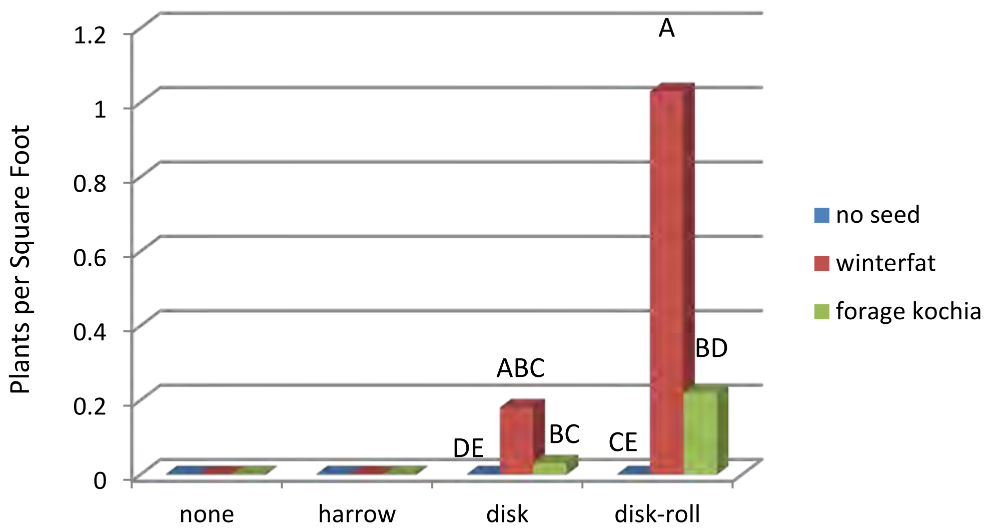

Figure 11. The densities of winterfat and forage kochia seeded into seedbeds with no preparation (none), harrowed, disked, or disked than rolled after seeding at Sites 2 and 3. Letters above bars indicate significant differences among seedbed treatments determined by ANOVA.

The ANOVA of the density data from Sites 2 and 3 found the effect of seedbed treatment on densities was dependent on the species seeded (P=0.0005). This interaction is shown in Figure 11. Winterfat established at about one plant per square foot in the disk-roll treatment, significantly greater than all other seedbed and species treatments except winterfat in the disk treatment. Winterfat density in the disked plots averaged 0.18 plants per square foot, significantly greater than where no seeds were broadcast in disked plots. Forage kochia density in the disk-roll treatment was about 0.2 plants per square foot and was significantly greater than where there were no seed inputs in the disk-roll treatment. From the ANOVA we conclude; 1) winterfat needs a disked seedbed (or similar treatment) to establish on these sites, 2) forage kochia needs a disk-roll treatment to establish on these sites.

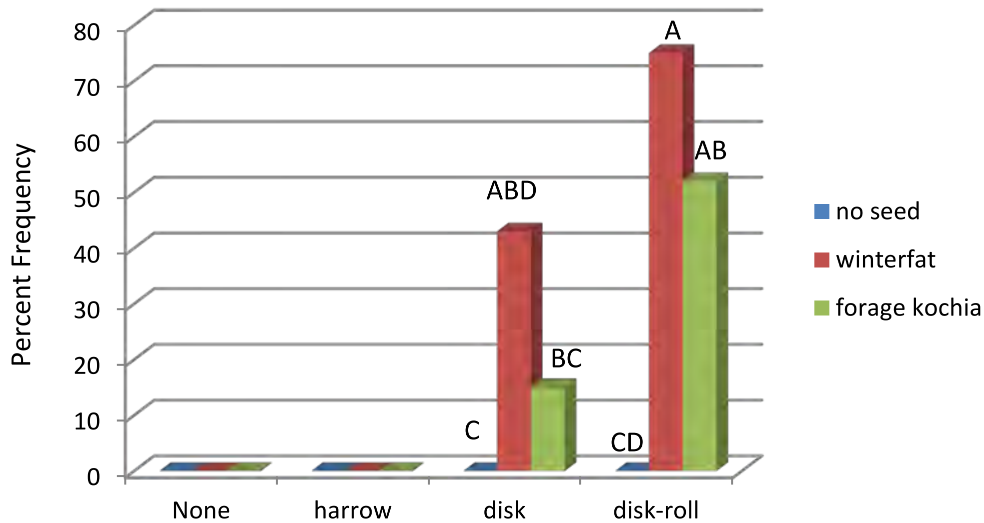

Figure 12. The mean frequencies of winterfat and forage kochia in each of the four seedbed treatments at Sites 2 and 3. Letters above bars indicate significant differences among seedbed treatments determined by ANOVA.

The ANOVA of the frequency of occurrence data from Sites 2 and 3 found the effect of seedbed treatment depended on the species seeded (P=0.0707). This interaction is shown in Figure 12. In the disk-roll treatment, winterfat (75%) and forage kochia (43%) were found in a greater percentage of the sample plots than where no seeds were broadcast (0%). In the disk treatment, only winterfat (52%), but not forage kochia (15%), was found in a greater percent of the sample plots than where no seeds were broadcast (0%). From the ANOVA we conclude; 1) to have even stand establishment of either of these species on these sites requires seed inputs, 2) on these sites and at these seeding rates, forage kochia needed a disk-roll treatment to improve frequency over no seed inputs whereas winterfat only needed the disk treatment.

Conclusion

It is notable that winterfat densities in the disk-roll treatments were statistically greater than the densities of forage kochia, but the frequency they were found in the sample plots was not statistically different. This suggests both winterfat and forage kochia can be introduced to pasture sites in south-central Montana when broadcast on a disked seedbed, and that rolling after seeding to improve seed-to-soil contact will improve establishment. Future evaluations will determine the long-term persistence of both species, an important question in crested wheatgrass stands and cheatgrass invasions. We believe both species will persist because their tap roots can extract moisture deeper in the soil than crested wheatgrass and cheatgrass and their canopies can overtop both grasses. We also plan to impose treatments to determine the influence of grazing on these species.

References

Harrison, R.D., N.J. Chatterton, B.L. Waldron, B.W. Davenport, A.J. Palazzo, W.H. Horton, and K.H. Asay. 2000. Forage kochia: Its compatibility and potential aggressiveness on intermountain rangelands. Research Report 162. Utah Agricultural Experiment Station. Utah State University. Logan, Utah. 66 p.

Menalled, F., J. Mangold, and E. Davis. 2008. Cheatgrass: Identification, biology, and integrated management. Montana State University Extension MontGuide MT200811AG. Bozeman, Montana. 4 p.

Ogle, D.E. 2006. Plant Guide for crested wheatgrass (*Agropyron cristatum*). USDA-Natural Resources Conservation Service, Aberdeen, ID Plant Materials Center. 83210-0296.

Ogle, D.G., St. John, L., Holzworth, L., Winslow, S.R., and D. Tilley. 2012. Plant Guide for winterfat (*Krascheninnikovia lanata*). USDA-Natural Resources Conservation Service, Aberdeen, ID Plant Materials Center. 83210-0296.

Tilley, D., Ogle, D., St. John, L. Waldron, B.L., and R.D. Harrison. 2012. Plant Guide for forage kochia (*Bassia prostrata)*. USDA-Natural Resources Conservation Service, Aberdeen Plant Materials Center. Aberdeen, Idaho 83210.

Appendix A

Statistical Analysis

Data from Site 1(Bales) were analyzed using a split-split-plot in time analysis of variance (ANOVA) model with seedbed treatment as the whole-plot independent variable, species seeded as the sub-plot independent variable, and year sampled as the sub-sub-plot independent variable. All interactions were tested. The ten density subsamples per plot were averaged and the averages were used as the dependent variables testing treatment effects and their interactions on density. The percent of the density subsamples with either winterfat or forage kochia was used as the dependent variable testing treatment effects on frequency of occurrence. Data were square root transformed as needed to meet the assumptions of ANOVA. Tukey's means separations procedure (α=0.05) was used when the *F*-test *P*-value was ≤0.1. The *P*-values for the density and frequency ANOVAs are shown in Table 1.

Table 1. The *P*-values from the ANOVA testing for significant species, year, and their interaction effects on densities and stand from data collected on Site 1.

Source	DF	Density	Frequency
Replication	2	0.5563	0.7585
Seedbed (SB)	3	0.0129	0.0386
Rep*SB (error)			
Species (Spp)	2	0.0008	0.0006
SB*Spp	6	0.0178	0.0129
Rep*SB*Spp (error)			
Year	1	0.0014	0.0192
Year*SB	3	0.0438	0.1102
Year*Spp	2	0.3218	0.9203
Year*SB*Spp	6	0.6778	0.7341

Data from Sites 2 and 3 (Murray and Paugh) were analyzed using a split-plot ANOVA model with seedbed treatment as whole-plot independent variable, species seeded as the sub-plot independent variable. The seedbed by species interaction was tested. The ten density subsamples per plot were averaged and the averages were used as the dependent variables testing treatment effects on density. The percent of the density subsamples with either winterfat or forage kochia was used as the dependent variable testing treatment effects on frequency of occurrence. Data were square root transformed as needed to meet the assumptions of ANOVA. Tukey's means separations procedure (α=0.05) was used when the *F*-test *P*-value was ≤0.1. The *P*-values for the density and frequency ANOVAs are shown in Table 2.

Table 2. The *P*-values from the ANOVA testing for significant species, year, and their interaction effects on densities and stand from data collected on Site 1.

Source	DF	Density	Frequency
Replication	2	0.6096	0.8066
Seedbed	3	0.0804	0.2396
Rep*SB (error)			
Species	2	<0.0001	<0.0001
SB*Spp	6	0.0005	0.0707