BONDERMAN FIELD STATION AT RIO MESA RUSSIAN KNAPWEED RESTORATION: NATIVE WINNER SEEDING TRIALS

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STUDY BACKGROUND: Located in Grand County, Utah the Bonderman Field Station at Rio Mesa is located along the red rock country of the Dolores River. It is owned and managed by the University of Utah. The project site has abandoned agricultural fields that by 2013 had become invaded with Russian knapweed (Acroptilon repens), which has outcompeted much of the native vegetation at the site. In 2013, funding from the USFWS Partners for Wildlife program and the University was used to treat and restore the knapweed site (about 42 acres of riparian and upland habitat). They hired a contractor (Conservation Seeding & Restoration Inc.) to carry out herbicide application and seeding, using native, commercially available seeds in 2013. The size of the site that was treated is about 42 acres of riparian and upland habitat. A large portion of this site was tilled a number of years ago, and knapweed is now at about 75% in this area (although some natives can be found). The untilled site has lower density of knapweed and higher density of native grasses, forbs, and shrubs. There is no 'standard' treatment for restoration of knapweed-invaded land. However, the approach that was taken at this site is:

1. Spray the knapweed with Milestone at the end of September 2013 before the first killing frost
2. Drill seed a mix of 9 native grasses in mid-November 2013
3. Retreat with Milestone again in the spring/summer 2014 (after grasses have become established)
4. Determine how to incorporate forb seeding into the site once grasses are established and Milestone no longer needs to be used to control Russian knapweed

We took advantage of the opportunity to incorporate an experimental approach to this restoration, and tested how the use of different native plant materials can impact the long-term outcomes of the restoration. Very little is known about which native species are most appropriate for post-knapweed restoration work like this, but most of the published literature is focused on 3-5 non-native species (mostly grasses and one forb; alfalfa). Building on research that has shown evolution of native species in knapweed-infested habitat (Ferrero-Serrano et al. 2011) and better suppression of invasive species when a diverse mix of species (including forbs) is sown into the restoration site (Mangold et al. 2007), we expect that post-knapweed seeding will be most effective if it contains a diverse mix of native species and seed sources that are suited for the restoration site. Our research goal was to test which native plant materials (species, sources, and mixes of species/seed sources) are most effective at long-term suppression of knapweed following herbicide treatment.

DATE PLOTS ESTABLISHED: In November 2013, we established ten long-term study plots throughout the restoration site (five in an area that had been tilled many years ago and was a monoculture of ACRE, and five in an adjacent area that hadn't been tilled and included ACRE as well as other shrubs and native species; Figures 1 and 2).

LOCATION DETAILS AND STUDY DESIGN: We have established ten long-term study blocks (Figure 2) throughout the restoration site to test which native plant materials (species, sources, and mixes of species/seed sources) are most effective at long-term suppression of knapweed following herbicide treatment. Each block is 10 x 10m with nine randomly-assigned treatment plots (Figure 3). Location details for each plot are described below, along with % cover of Russian knapweed in summer 2013 prior to the application of Milestone.

Study block locations whether or not they had been previously tilled, and % knapweed cover at the beginning of the restoration project (see Appendix 1-3 for more details):

Block#	Latitude	Longitude	Tilled?	% knapweed cover
1	38.79977	-109.1784	No	25-50%
2	38.80009	-109.1778	No	25-50%
3	38.80075	-109.1785	No	25-50%
4	38.80056	-109.1775	No	25-50%
5	38.8007	-109.1792	No	5-10%
6	38.80013	-109.1789	Yes	50-75%
7	38.79995	-109.1798	Yes	25-50%
8	38.79934	-109.1792	Yes	50-75%
9	38.79918	-109.1786	Yes	25-50%
10	38.79932	-109.1777	Yes	50-75%

Within each block, nine 3x3 m plots were randomly assigned one of the following treatments:

1. No herbicide, no seed
2. Herbicide, no seed
3. Standard seeding mix (see Appendix 4 for details)
    a. 9 native grasses applied by CSR at seeding rate of 61.5PLS/ft2
4. Standard seeding mix + future addition of forbs
    a. Forbs not sown due to lasting effects of Milestone and potential for retreatment, so treatment combined with TRX3.
5. Local seeding mix (see Appendix 4 for details)
    a. Locally-sourced seed for 7 of the same 9 native grass species used in Trx3 at seeding rate of 61.5PLS/ft2
6. Local seeding mix + future addition of forbs
    a. Forbs not sown due to lasting effects of Milestone and potential for retreatment, so treatment can be lumped with TRX5.
7. Grass monoculture (9 native grasses, mostly local source, grown in monoculture subplots)
    a. Not established in all blocks b/c of presence of rabbitbrush and/or rocks/cryptobiotic crust
8. Space for forb monoculture plots
    a. Forbs not sown due to lasting effects of Milestone and potential for retreatment .
    b. Nora Talkington set up seed germination trials using SPAR seeds glued to toothpicks in 2014, but no germination. Plots weeded prior to establishing the toothpick study, so NOT OK to combine with TRX2 (herbicided, nonseeded control plots).
9. *Sporobolus airoides* seed source trial (established May 2014)
    a. N. Talkington MS thesis – results reported separately

<u>Methods</u>

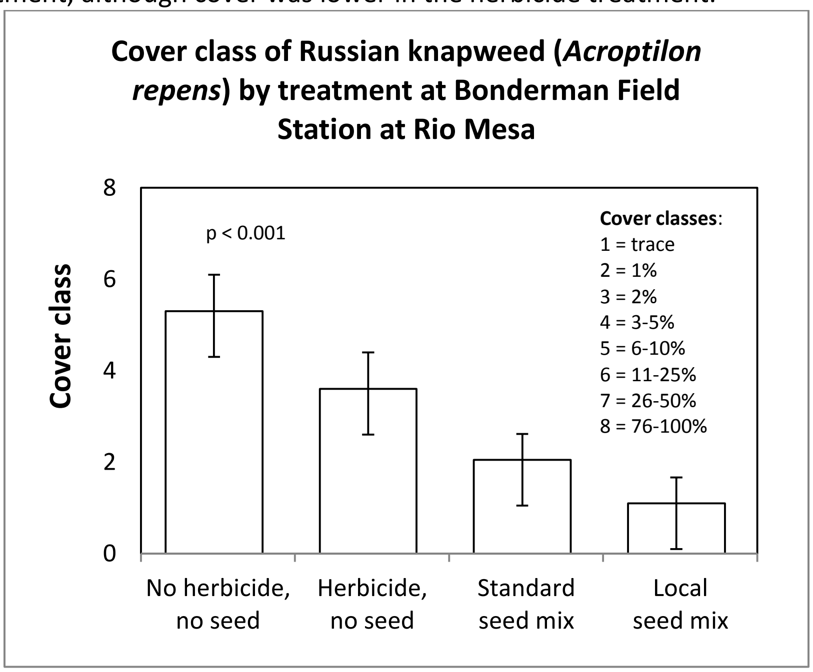
1. **Plots established**: *Summer 2013 (visits in May, June, September, and November)*:
    a. Work with SOS collectors and CPNPP collaborators to locate and/or collect target native species for "LOCAL" treatment.
    b. Establish ten 10x10m blocks (5 in the previously tilled portion of the field, 5 in the untilled portion) each with nine 3x3m plots for treatment application (one treatment as above/block).
    c. Conduct vegetation surveys to inform post-treatment work.
    d. Collect soil from each plot for small soil seed bank study (collected September 2013; trials performed in growth chambers at Chicago Botanic Garden winter 2013 – summer 2014).
2. **Treatments applied**: *Fall/Winter 2013*:
    a. September 16th - CSR applied Milestone (TRX1 plots in our study covered with a plastic tarp).
    b. Nov 6th - Received seeds from CSR. Seeds already bulked so challenging to prepare for monoculture plots. Some species isolated with sieves (e.g., ACHY) but not all
    c. Nov 7 -9 - grass seed treatments applied to study plots (raked in)
    d. Nov 10 - vegetation survey data taken to assess effectiveness of Milestone treatment.

e. Nov 11 - CSR drill seeded the entire field (except our 10 study blocks)
f. Spring 2014 - spot application of Milestone to the field except our study plots?
g. May 2014 - Nora Talkington study plots with Alkali sacaton plugs (Trx9). Results reported separately.

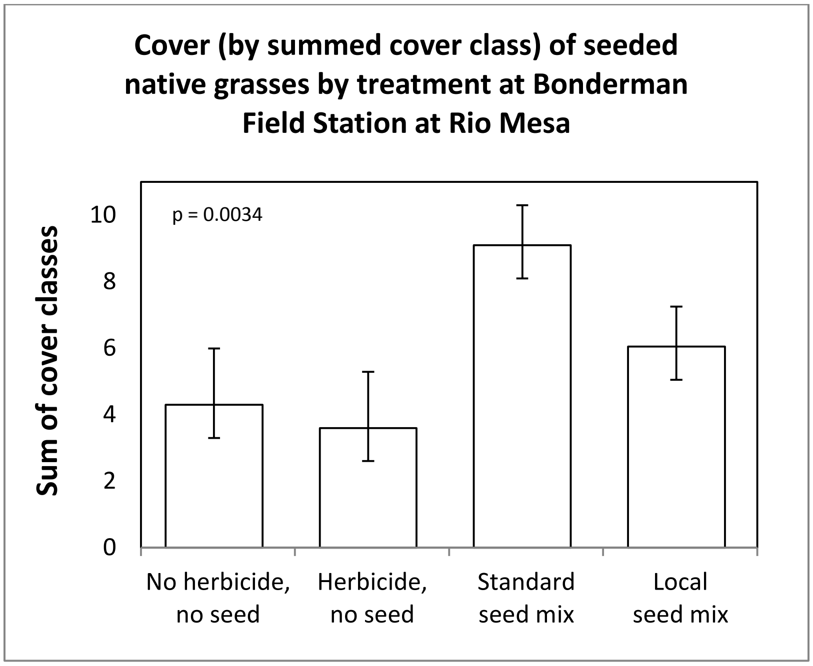
3. **Vegetation survey completed**: *Spring 2016*
    a. Vegetation data (species and % cover by plot) recorded in May 2016 by (Talkington & Eshleman).
    b. Plots remain in place to allow future surveys.
4. **Analyses**
    a. Ordinal logistic regression in JMP
        i. % ACRE cover in 2016 with block as random effect
        ii. % cover of seeded grasses (individually) in 2016 with block as random effect
        iii. % cover of species identified (individually) in 2016 with block as random effect
        iv. % cover of all seeded grasses in 2016 (cover classes summed) with block as random effect
    b. LM in JMP
        i. % cover of binned cover types (native grasses, native forbs, etc ; cover classes summed = continuous/normal) with block as random effect
        ii. % cover of all vegetation (cover classes summed = continuous/normal) with block as random effect

Results

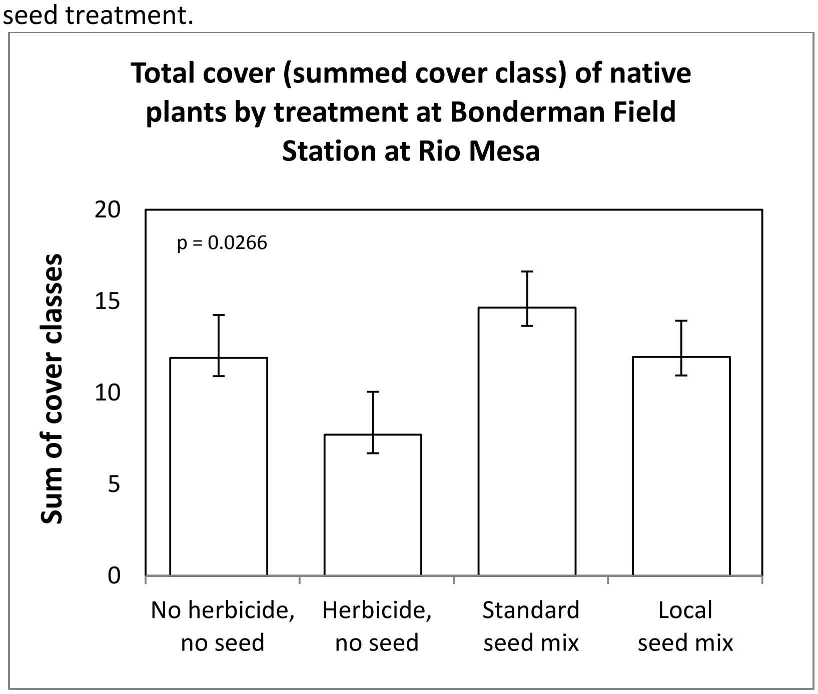
Not all species were present two-years following seeding. The species with greatest aboveground cover were *Achnatherum hymenoides, Bouteloua gracilis, Hesperostipa comata,* and *Sporobolus cryptandrus* (see Appendix 4). There was a significant effect of treatment on the cover of ACRE in 2016 (p < 0.001 – see figure below). The primary difference was between the herbicide no seed treatment and the seeding treatments. There was no significant difference between the local and standard treatments, although the local treatment had the lowest cover of ACRE. There was also no significant difference between the no herbicide no seed treatment and the herbicide no seed treatment, although cover was lower in the herbicide treatment.



The only significant treatment effects on different classes of vegetation cover was on Seeded Native Grasses (p = 0.0034, Chi-square = 13.68 – see figure below) and Total Native Grasses (p = 0.0078, Chi-square = 11.87), where the standard seed mix was significantly greater than the herbicide, no seed treatment, but no other treatments were significantly different from one another. However, the local treatment tended to have less cover of seeded native grasses than the standard treatment, both of which had less cover than the herbicide and seeding control treatments.



There was no treatment effect on the cover of non-native species, but there was a small treatment effect on the total cover of native species (p = 0.0266, F=3.36), with the standard seed mix treatment again significantly greater than the herbicide, no seed treatment.



Discussion

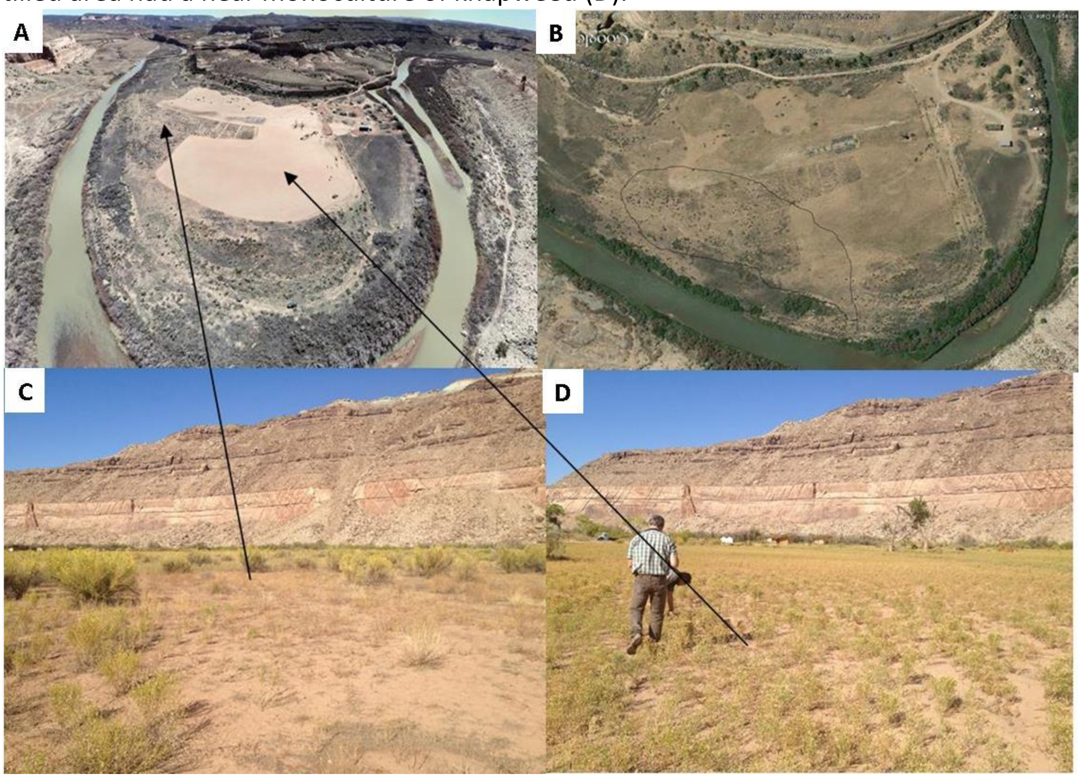
Two years post-treatment, there was less cover of the target invasive species (Russian knapweed) in the seeded treatments than the unseeded treatments, and no significant difference between the herbicided and unherbicided treatments. The local seed mix tended to have lower cover of knapweed than the standard seed mix, but this was not a significant difference. However, it is interesting to consider potential causes of the seeding effects – while there was again no significant difference between the standard and local mix treatments in measures of native or non-native cover, the standard seed mix plots tended to have greater percent cover than local plots. This suggests that belowground processes may be impacting the cover of knapweed more than aboveground processes, and warrants further investigation.

Citations

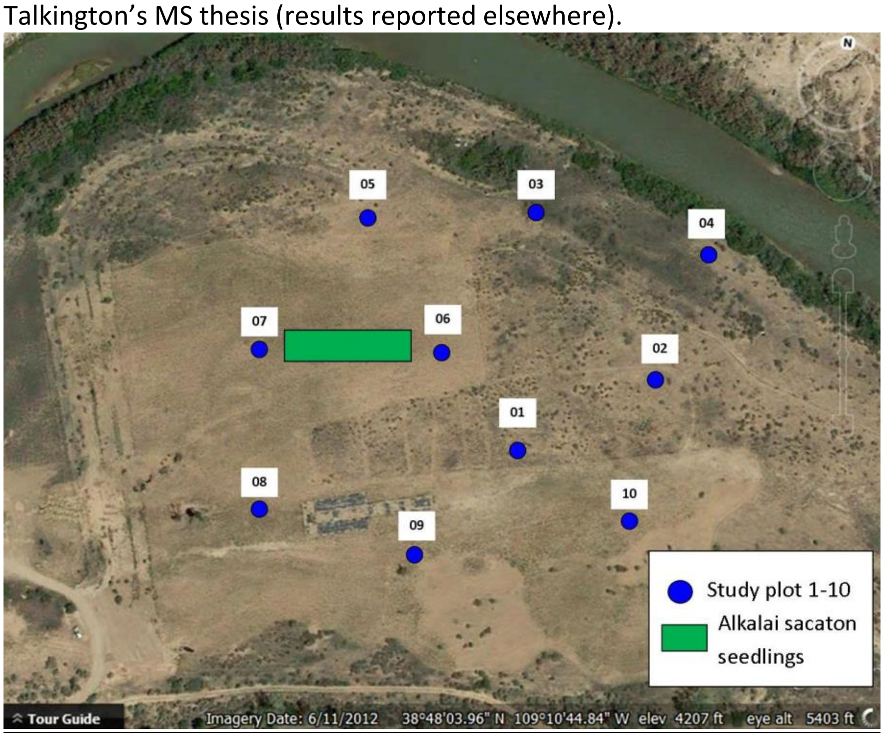
Ferrero-Serrano, Á., A. L. Hild, and B. A. Mealor. 2011. Can Invasive Species Enhance Competitive Ability and Restoration Potential in Native Grass Populations? Restoration Ecology **19**:545-551.

Mangold, J. M., C. L. Poulsen, and M. F. Carpinelli. 2007. Revegetating Russian knapweed (*Acroptilon repens*) infestations using morphologically diverse species and seedbed preparation. Rangeland Ecology & Management **60**:378-385.

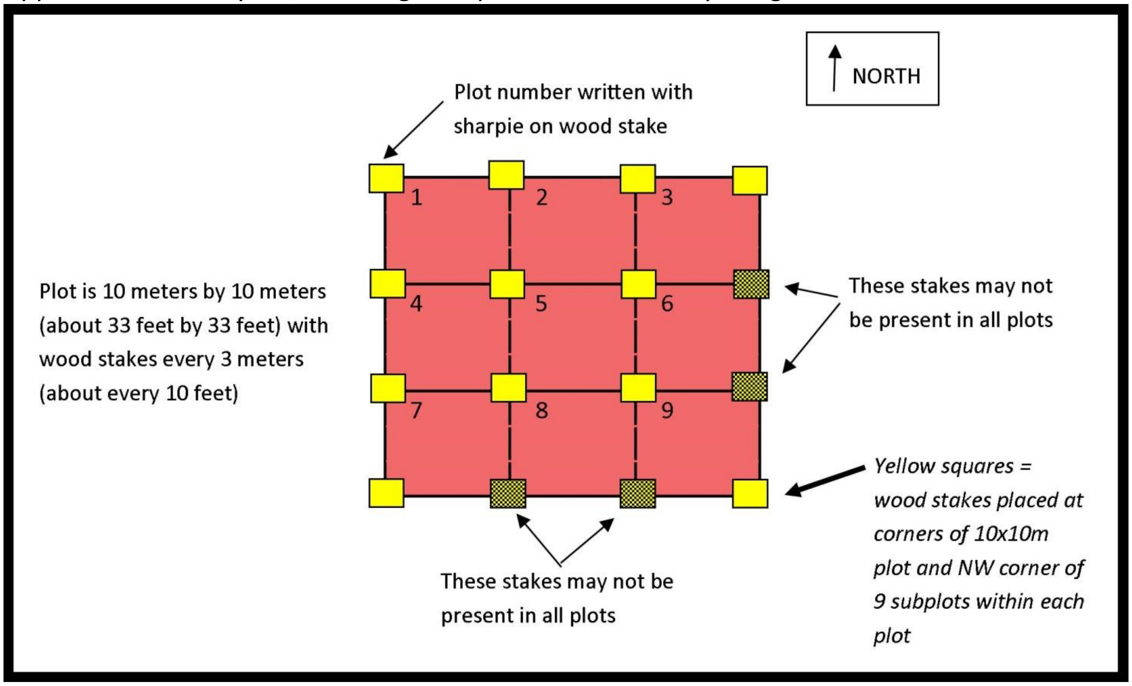
Appendix 1: Treatment area – note area that was tilled in the early 2000's (A) is still visible in 2012 (B). The untilled area had a relatively low density of knapweed growing with other native shrubs, grasses, and forbs (C: including the shrub *Ericameria nauseosa* and the forb *Machaeranthera canescens*) prior to treatment, but the tilled area had a near monoculture of knapweed (D).



Appendix 2: Layout of 10 study blocks and common garden for *Sporobolus airoides* as a part of Nora Talkington's MS thesis (results reported elsewhere).



Appendix 3 Block layout, including nine plots with randomly-assigned treatments.



Appendix 4: Seeding details for Standard and Local seed mix treatments, including the source where seed came from and the seeding rate used. Results reported as average cover class for each treatment during May 2016 vegetation survey.

Treatment	**USDA Code**	**Scientific Name**	**Standard TRX Source/Cultivar**	**Local TRX Source/Cultivar**	**Avg Cover Class* Standard TRX**	**Avg Cover Class* Local TRX**
STANDARD	ACHY	*Achnatherum hymenoides*	Nezpar	White River	1.15	1.9
STANDARD	BOGR	*Bouteloua gracilis*	Lovington	SOS-CP1-170	2.2**	0.35
STANDARD	ELEL	*Elymus elymoides*		UP (Ken Holsinger)	0	0
STANDARD	ELLA	*Elymus lanceolatus*	Critana	NONE	0	0
STANDARD	HECO	*Hesperostipa comata*		NONE	2.8**	0
STANDARD	LECI	*Leymus cinereus*	Magnar	NONE	0.2	0.35
STANDARD	PLJA	*Pleuraphis jamesii*	Viva	SOS-CP1-166 and on-site collection	0.2	0
STANDARD	SPAI	*Sporobolus airoides*		SOS-CP1-133	0	0
STANDARD	SPCR	*Sporobolus cryptandrus****		SOS-CP1-171 & SW Seed	3.25	2.75

*Cover classes: 1 = trace, 2 = 1%, 3 = 2%, 4 = 3-5%, 5 = 6-10%, 6 = 11-25%, 7 = 26-50%, 8 = 76-100%

** Significantly greater than other treatments ($p < 0.001$)

*** On-site and in seed bank