RUSSIAN KNAPWEED GERMINATION AND GRAZING/HERBICIDE TRIALS PRELIMINARY RESULTS

Principal Investigators
Larry Larson, Mike Borman, and Gary Kiemnec

Cooperators
Leslie Richman, BLM; V. Carrithers, Dow Agro;
Michael Carpinelli, ARS; Ms. Alden, Landowner;
David Chamberlain, OSU Extension Service

Summary

Russian knapweed is a noxious weed on rangelands that has proven difficult to control. Germination and grazing/herbicide trials were developed to evaluate germination requirements and infestation response to coordinated grazing and herbicide treatment. Results from the germination trials indicate that germination is limited to areas where wetted soil conditions are maintained for extended periods of time (minimum ~7 days peak germination ~ 25–32 days) and community structural characteristics afford an opportunity for seed coverage by litter or soil. Grazing treatments in 2003 removed 1,400 and 2,600 lbs of knapweed per acre. The crude protein content of the knapweed was 18 percent in June declining to 7 percent by late August. Based on visual observation, goats gained weight and did not show any visible negative effects from the knapweed diet.

Introduction

Russian knapweed (*Centaurea repens*) is a perennial noxious weed that is native to Eurasia (Bottoms and Whitson 1998). It has become particularly troublesome in the semiarid Intermountain West, colonizing saline and non-saline riparian habitats as well as other areas having seasonal shallow water tables.

Russian knapweed reproduces by seed and creeping rootstock and has proven to be a difficult weed to manage on infested rangelands. One author describes Russian knapweed as the most persistent and difficult perennial knapweed to control (Lacey 1989). After initial establishment by seed, infestations of knapweed tend to maintain and spread via adventitious roots rather than through the continued establishment of new seedlings (Watson 1980). Chemical control of established infestations typically requires re-treatment within 3–5 years to maintain adequate control (Bottoms and Whitson 1998). Picloram, clopyralid, and imazapic are three chemicals that show promise for Russian knapweed control. However, rootstock control remains illusive. McInnis et al. (2003) reported increased herbicide effectiveness (rootstock control) on hoary cress regrowth following a mechanical mowing treatment. In that case it was observed that hoary cress regrowth was more uniform in structure and development following treatment and was likely weakened by biomass removal improving the effectiveness of herbicide control on rootstock.

The purpose of the germination trial was to determine the response of Russian knapweed seed to light, decreasing water potential and increasing salinity. The objective of the coordinated grazing (goats)/herbicide trial was to determine if treatment combinations would improve rootstock control of Russian knapweed. The field plots are designed to continue through a grass stand establishment phase, which will begin in fall 2004.

Results and Discussion

Ruminal incubation or soaking in water increased germination 13-fold or 15-fold, respectively, compared to seeds that were kept dry prior to the germination test (Fig. 1).

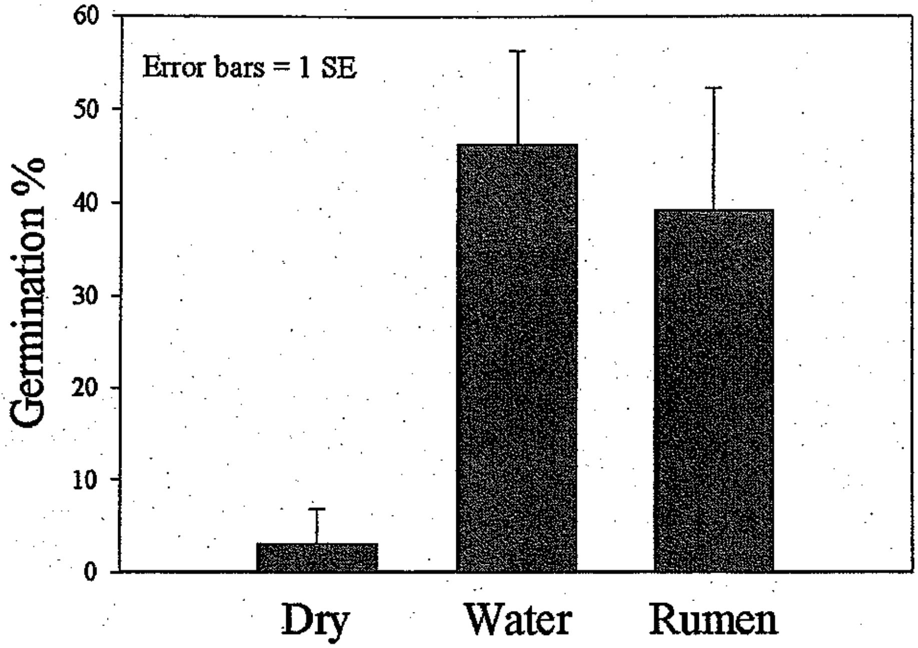

Figure 1. Germination of perennial pepperweed seeds that were soaked in water or ruminally incubated increased more than 10-fold compared to seeds that were kept dry prior to being tested for germination.

Germination did not significantly differ between ruminal incubation and soaking in water. These results suggest that spread of perennial pepperweed may be reduced by controlling it in areas where its seeds may eventually be transported by water (e.g., riparian areas, flood meadows, and irrigation ditches). These results also suggest that if livestock graze perennial pepperweed that has gone to seed, they should be held on weed-free forage for about 1 week prior to being moved to uninfested areas where otherwise, viable perennial pepperweed seeds may be deposited in their dung. Ideally, it may be best to graze perennial pepperweed at the time of flowering to reduce the likelihood that enough growing season or soil moisture will remain to allow grazed plants to flower again and set seed in the same year.

Methods

Germination trial

Russian knapweed seed was collected in 2002 from plants growing in riparian and other low landscape positions within the sagebrush steppe of northeastern Oregon. Watson (1980) reported that knapweed seed production was subject to high rates of seed abortion. Field observations made in 2001 and 2002 suggest that viable seed production is sensitive to summer soil moisture. Knapweed populations were field tested to avoid populations dominated with unfilled seed. Collected seed was stored in plastic grain sacks for 3 months before being removed from the seed heads, cleaned, and separated to avoid shriveled seed for germination studies.

All germination experiments (68°F) were set up in completely randomized designs with four replications. Preliminary germination trials indicated that the germination experiments would run 40 days and require a fungicide treatment. Russian knapweed seeds were rinsed in a 5 percent sodium hypochlorite solution, followed by three distilled water rinses prior to the start of each germination trial. The experimental unit consisted of 50 seeds placed on two sheets of filter paper (Whatman No. 1) in a 100- by 15-mm Petri dish. All experiments were designed to contrast germination under light (500 $uEm^{-2}s^{-1}$ spectral light) and dark conditions.

In the first set of experiments seeds were exposed to four levels of osmotic potential (polyethylene glycol concentrations [PEG]): 0, -0.5, -1.0 and -1.5MPa. Osmotic potentials were verified with a Wescor C-51 thermocouple psychrometer. Hardegree and Emmerich (1990) reported that filter paper selectively absorbed water from PEG solution, thus decreasing the effective osmotic potential that the seed would be exposed to on the filter paper surface. Using the correction equations given in this paper, the actual osmotic potentials were determined to be unchanged.

In the second set of experiments seeds were exposed to five levels of increasing salinity. NaCl and $CaCl_2$ were mixed to achieve electrical conductivities of 0, 4, 8, 12 and 16 dSm^{-1} and a sodium absorption ratio of 2. Electrical conductivities were verified with a conductivity meter. The salt solution gradient approximated 0, -0.12, -0.23, -0.35 and -0.47 MPa (Richards 1954).

Germination counts were taken daily for 40 days. Germination was considered to have occurred at radical emergence. All germinated seeds were removed at each count and treatment solutions were renewed as needed.

Differences among treatment effects were tested by analysis of variance. Mean separation was achieved with least significant difference (LSD) comparisons. Simple linear regressions ($R^2 > 0.85$) were performed to predict rates of germination and the initial date of germination. Differences among the initial date of germination and germination rate estimates were determined using analysis of variance with LSD comparisons. All reported results are significant at $P \leq 0.05$ unless otherwise stated.

Grazing/herbicide trials

The grazing/herbicide trial is being conducted on a site near Burns, Oregon. Preliminary results are reported at this time. All reported results are significant at $P \leq 0.05$ unless otherwise stated. The study area lies within a heavy infestation of Russian knapweed that currently occupies several hundred acres. A split plot experimental design (three blocks) was employed using fall herbicide treatments of control, picloram at 1qt/acre, clopyralid at1.33pt/acre, and imazapic at 12oz/acre coordinated with three grazing treatments in the first year. Grazing treatments consist of no grazing, grazing once during the growing season, and grazing twice during the growing season. A second experimental design was duplicated on the site to test the value of extending the grazing treatment over two growing seasons before applying the fall herbicide treatments. Preliminary trials were conducted in 2002 that verified the willingness of the goats to select knapweed as a major component of their diet.

Results

Germination trial

Russian knapweed germination was completely inhibited at all levels of water stress imposed by PEG (data not shown). Germination at 0.0 MPa was greater under continuous dark conditions when contrasted against a continuous light environment (Table 1). Differences in light versus dark germination among knapweed seed occurred 12 days into the experiment. At the end of the germination trial (40 days), Russian knapweed germination under dark conditions was one and a half times greater than under light conditions (62 versus 39 percent).

Table 1. Cumulative knapweed germination in a light versus dark environment at 0.0 MPa.

Day	Dark	Light	LSD (0.05)
	——— % ———		
4	0	0	--
8	3.0	1.6	--
12	8.0	3.2	3.0
16	13.4	5.2	3.9
20	23.4	10.4	4.4
24	31.0	13.6	3.7
28	43.0	21.0	3.7
32	55.2	30.4	8.0
36	60.4	35.6	10.1
40	61.4	39.2	8.3

Knapweed germination was greatest between days 25 and 32 of the experiment regardless of the light treatment (Table 2). Approximately 40 percent of all germination occurred during the 8-day period. The rate of knapweed germination during the first 36 days of the experiment was two times greater in a dark environment when compared to a light environment (1.0 versus 0.5 germinations/day). Light and dark treatment did not influence the number of days required before germination was detected. Germination required approximately 1 week of exposure at near saturated conditions and continued for the next 25 days if moisture conditions were maintained before a decline in germination became evident and the experiment was terminated.

Germination of Russian knapweed seed decreased with increased salt concentration. In a dark environment (40-day germination totals), germination in the non-saline control was greater than 8, 12 and 16 dSm^{-1} (62 versus 49, 31 and 23 percent). Germination at 4 dSm^{-1} (57 percent) was intermediate to germination amounts observed in non-saline and 8 dSm^{-1} treatments. These results suggest that Russian knapweed germinates across a wide spectrum of salt concentration, if sufficient moisture is present. Saline soils are defined as having salt concentrations above 4 dSm^{-1} (Miller and Donahue 1990). Cumulative germination after 36 days of the experiment was reduced 10 percent for each treatment increase in dSm^{-1} (germination count = 31.7 - 1.3(dSm^{-1}), $R^2 = 0.86$). The rate of germination during the first 36 days of the experiment increased 40 percent as salinity was reduced from 16 to 12 dSm^{-1} (0.3 versus 0.5 germinations/day) and 12 to 8 dSm^{-1} (0.5 versus 0.7 germinations/day). The rate of germination increased 20 percent with salinity reductions from 8 to 4 and 4 to 0 dSm^{-1} (0.7 versus 0.8 and 0.8 versus 1.0 germinations/day).

Table 2. Knapweed germination during each 8-day period in light and dark environments.

Day	Dark	Light[1]	Mean[2]
	------------------	%	---------------
0-8	3.0a	1.7a	3.0d
9-16	10.4a	3.4b	7.5c
17-24	17.4a	8.4b	15.0b
25-32	24.2a	15.0b	18.6a
33-40	6.2a	8.6a	8.1c

[1] Letter differences across treatment columns are different at $P < 0.05$.

[2] Mean period (8-day) comparisons are vertical ($P < 0.05$).

Under continuous light conditions, germination was greatest in the non-saline control (39 percent). Germination at 4 and 8 dSm^{-1} was similar, but 44 percent less than the control. Germination at 12 and 16 dSm^{-1} had the least amount of germination and averaged 84 percent less germination than the control. Cumulative germination after 36 days of the experiment was reduced 8 percent for each treatment increase in dSm^{-1} (germination count = 17.1 - 1.0 [dSm^{-1}], $R^2 = 0.79$).

Grazing/herbicide trial

Experimental plots were established in spring 2003 within an infestation of Russian knapweed growing on a fine-loamy, mixed, superactive, frigid Vitritorrandic (Calcidic) Haploxeroll. The fenced perimeter of the experiment contains 6 acres.

Pre-treatment conditions
June 2003
First week

Stem density—Stem density was determined from $0.2m^2$ plots. Each treatment cell (36) within the experiment was sampled using two randomly placed plots in the center of the cell ($n = 72$). Treatment cell differences were not detected within the 2-year grazing experiment. Russian knapweed stem density (m^2) was 44 ±4 (mean ± standard deviation), hoary cress (*C. draba* + *pubescens*) density (m^2) was 83 ± 8. Within the 1-year grazing experiment, treatment cell differences were not detected for Russian knapweed but block 2 did contain more hoary cress stems than blocks 1 and 3. Russian knapweed stem density (m^2) was 53 ± 2. Hoary cress stem densities (m^2) were 90 stems in blocks 1 and 3 compared to 117 stems in block 2 (LSD = 25).

Biomass—Russian knapweed and hoary cress biomass ($0.25m^2$; oven dry) estimates were determined from 20 plots. Weed biomass was 1,430 ± 230 lbs/acre (mean ± 95 percent confidence interval). Russian knapweed and hoary cress comprised 77 and 23 percent of the biomass, respectively.

July Data
First Week

Control biomass—Control plot biomass (20 plots; $0.25m^2$) was 2,500 ± 400 lbs/acre (mean ± 95 percent CI). Russian knapweed and hoary cress comprised 92 and 8 percent of the biomass, respectively. This represented a 1,100-lb increase in the mean biomass estimate compared to the June estimate.

Grazing treatment one—Four hundred doe and kid goats were placed within the experimental plots on June 17 for 5 days. The biomass (20 plots; $0.25m^2$) at the end of the grazing treatment was 1,100 ± 200 lbs/acre (mean ± 95 percent CI). Russian knapweed contributed 99 percent of the biomass within the experimental plots. The grazing treatment achieved 55 percent utilization.

August Data
Fourth week

Control biomass—Control plot biomass (20 plots; $0.25m^2$) was 2,400 ± 300 lbs/acre (mean ± 95 percent CI). Russian knapweed made up 97 percent of the plot biomass. The difference between the July and August biomass estimates do not represent a measurable decline in biomass.

June grazed plots—The experimental plots grazed in June contained 1,700 ± 300 lbs/acre (mean ± 95 percent CI) prior to the August grazing (20 plots; $0.25m^2$). This represents a 600-lb growth increase in mean biomass between the July and August grazing treatments. The biomass contained in the experimental plots was 100 percent Russian knapweed.

August grazed plots—The second grazing treatment placed 400 doe and kid goats on the designated treatment plots for a second grazing period (August 26–28) of 3 days. The biomass (20 plots; $0.25m^2$) at the end of the second grazing treatment was 500 ± 100 lbs/acre with 100 percent of the biomass being Russian knapweed. The second grazing period achieved 70 percent forage utilization.

Discussion

Germination trial

Continuous light has been observed to inhibit germination in a number of species (Bradbeer 1988, Bewley and Black 1994) and is generally associated with species that favor seed burial or shaded environments. Our results suggest a knapweed germination strategy that favors seed burial and/or shaded environments for germination. Results from the moisture tests indicate that seeds require exposure to moisture conditions near field capacity for approximately 7 days for germination to begin and exposure to that environment for 25 to 32 days yielded the highest daily rate of germination. Knapweed germination decreased with exposure to increased salt concentrations. However, for practical purposes, most sites classified as saline would result in only a moderate reduction in germination.

In the sagebrush steppe, knapweed populations are maintained primarily through vegetative reproduction (creeping root system). Seed development is sensitive to summer soil moisture and appears to result in spotty viable seed production. Knapweed seed is suited to germinate in riparian, wet meadow, sodic meadow and meadow environments. In the wettest years germination could expand to alluvial fans and toe slopes where topographic attributes concentrate soil moisture. However, successful knapweed germination is probably limited to areas where wetted soil conditions are maintained for extended periods of time and community structural characteristics afford an opportunity for seed coverage by litter or soil.

Grazing/herbicide trial

The control plots ended the growing season with 2,400 ± 300 lbs/acre of standing biomass. Peak biomass occurred in the control plots in late June. Plots receiving one grazing period ended the growing season with 1,700 ± 300 lbs/acre of standing biomass. The grazing treatment removed approximately 1,400 lbs/acre of biomass in June and growth within the experimental plots during July and August contributed 600 lbs/acre. Forage utilization under this treatment was 55 percent.

Plots receiving two grazing periods ended the growing season with 500 ± 100 lbs/acre of standing biomass. The first grazing period removed 1,400 lbs/acre of biomass in June, re-growth on the plots in July and August contributed 600 lbs/acre (total biomass = 1,700 ± 300 lbs/acre). The second grazing period removed 1,200 lbs/acre from the plots resulting in an end of season biomass of 500 ± 100 lbs/acre. Approximately 2,600 lbs/acre of knapweed and hoary cress biomass was removed by this treatment strategy. Forage utilization under this treatment was 55 percent in the first grazing period and 70 percent in the second grazing period.

The nutrient content of Russian knapweed and hoary cress was relatively high in June but declined with maturity (Table 3). Goats grazed a steady knapweed diet throughout the summer of 2002 and 2003. They were observed to gain weight and did not appear to exhibit any visible toxic effects.

Table 3. Knapweed and hoary cress nutrient content in June and August 2003.

Nutrient	June		August	
	Knapweed	Hoary cress	Knapweed	Hoary cress
	------------ %	------------	----------- %	-----------
--				
Crude Protein	18.5	15.3	7.4	7.4
ADF[1]	32.2	22.8	44.4	32.0
NDF[2]	43.4	33.9	63.3	45.8
TDN[3]	58.0	62.0	54.0	58.0

[1]ADF = acid detergent fiber
[2]NDF = neutral detergent fiber
[3]TDN = total digestible nutrients

Herbicide treatments were applied in mid-October 2003 to the 1-year grazing blocks. Herbicide treatments were control, picloram at 1qt/acre, clopyralid at 1.33pt/acre, and imazapic at 12oz/acre. An assessment of knapweed and hoary cress density and biomass will begin in summer 2004. Seeding trials will begin in fall 2004.

Literature Cited

Bewley, J., and M. Black. 1994. Seeds: physiology of development and germination. Second Ed. Plenum Press. New York, NY.

Bottoms, R., and T. Whitson. 1998. A systems approach for the management of Russian knapweed (*Centaurea repens*). Weed Tech. 12: 363–366.

Bradbeer, J. 1988. Seed dormancy and germination. Chapman and Hall. New York, NY.

Hardegree, S., and W. Emmerich. 1990. Effect of polyethylene glycol exclusion on the water potential
of solution-saturated filter paper. Plant Physiol. 92:463–466.

Lacey, C. 1989. Pages 1–6 *in* Proc. Knapweed Symp. Bozeman, MT. Montana State University Extension Bull. 45.

McInnis, M., G. Kiemnec, L. Larson, J. Carr, and D. Sharratt. 2003. Heart-podded Hoary Cress. Rangelands 25:18–23.

Miller, R., and R. Donahue. 1990. Soils: an introduction to soils and plant growth. Prentice–Hall Inc., Englewood Cliffs, NJ.

Richards, L. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handb. 60, U.S. Government Printing Office, Washington, DC.

Watson, A. 1980. The biology of Canadian weeds. 43. *Acroptilon (Centaurea) repens* (L.) DC. Can. J. Plant Sci. 60:993–1004.