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# Relationships among Idaho fescue defoliation, soil water, and spotted knapweed emergence and growth

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## Abstract

**Developing rangeland management strategies to minimize spotted knapweed (*Centaurea maculosa* Lam.) invasion will require understanding the effects of intensity, frequency, and season of grazing on weed establishment. We studied the effects of hand-clipping 2-year-old Idaho fescue (*Festuca idahoensis* Elmer) plants 0, 30, 60, or 90%, 1, 2, or 3 times (14-day intervals) on spotted knapweed seedling emergence and growth in pots watered with 150 ml once weekly or 50 ml 3 times weekly. Pots were seeded with 5,000 spotted knapweed seeds $m^{-2}$, replicated twice, and placed in a growth chamber in a completely randomized design. The experiment was repeated once. Plants were harvested after 50 days. Treatment effects on soil moisture, Idaho fescue and spotted knapweed shoot and root weight, and leaf area were compared using analysis of variance and regression analysis. At final harvest, Idaho fescue shoot weight and leaf area decreased with increasing defoliation level and frequency. Idaho fescue root weight was not affected by any treatment. A single Idaho fescue defoliation at 30% and 90% increased spotted knapweed weight and numbers per pot respectively, over those pots with undefoliated plants. The level of defoliation necessary to enhance spotted knapweed numbers was lower as defoliation frequency increased. As defoliation level and frequency increased, soil water content increased resulting in a corresponding increase in spotted knapweed emergence and growth.**

**Key Words: *Centaurea maculosa* Lam., *Festuca idahoensis*, Elmer, clipping, weed invasion, grazing management**

Spotted knapweed (*Centaurea maculosa* Lam.), an alien weed, has been spreading rapidly into Idaho fescue (*Festuca idahoensis* Elmer.), rough fescue (*Festuca scabrella* Torr.), and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith) dominated rangeland throughout the western United States (Roché and Talbott 1986) and Canada (Watson and Renney 1974). Herbarium records indicate a 4-fold increase in the number of counties with new introductions of this weed in 5 northwestern states during the past 20 years. In Montana, spotted knapweed has been spreading at a rate of 27% per year, infests about 2.2 million hectares, and has the potential to invade a total of 15 million hectares (Chicoine et al. 1985). Spotted knapweed reduces livestock and wildlife forage production (Bucher 1984; Spoon et al. 1983), increases surface water runoff and soil sedimentation (Lacey et al. 1989), and lowers plant diversity (Tyser and Key 1988).

Although spotted knapweed can invade in the absence of livestock grazing (Tyser and Key 1988), rapid invasion of rangelands by knapweeds is commonly associated with improper grazing. Invasion may be enhanced by selective and excessive grazing of desirable forage species (Lacey et al. 1990). The relationship between grass defoliation and spotted knapweed establishment may depend on the level and frequency of grass defoliation and the amount and frequency of precipitation during the establishment period. In a field study, a single grass defoliation greater than 60% of the canopy increased diffuse knapweed (*Centaurea diffusa* Lam.) establishment (Sheley et al. 1997). In that study, high spring precipitation appeared to favor knapweed seedling establishment. Similarly, spotted knapweed seedling emergence increased with increasing soil moisture in a controlled environment (Spears et al. 1980). Grass species have different responses to defoliation frequency (Alexander and Thompson 1982); however, most studies show increasing defoliation frequency reduces yield (Cook et al. 1958, Undersander and Naylor 1987). Interactions between defoliation level and defoliation frequency and their effects on spotted knapweed establishment have not been studied.

Developing strategies to minimize weed invasion requires understanding the relationship between the intensity, frequency, and season of grass defoliation on establishment and growth of spotted knapweed. The objective of this study was to determine the effect of Idaho fescue defoliation level and frequency under 2 watering regimes on soil water content and spotted knapweed seedling emergence and growth. We hypothesized that as defoliation level and frequency increase, soil water content will increase, resulting in a corresponding increase in spotted knapweed emergence and growth.

## Materials and Methods

### Experimental Design

Idaho fescue plants were established from seeds in 63 mm diameter × 250 mm depth (600 $cm^3$) pots consisting of 1/3 Farland silt loam (fine-silty, mixed Typic Argiboroll), 1/3 peat,

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and 1/3 sand. Seeds were collected in 1992 from Sanders County, Mont. Grasses were grown for 18 months in a greenhouse until leaf material covered more than 50% of the soil and their roots completely occupied the pots.

Treatments (4 defoliation levels, 3 frequencies, 2 watering regimes) were replicated twice in a completely randomized design and repeated once. Defoliation treatments were applied by hand-clipping grasses in each pot. Defoliation levels were 0, 30, 60, or 90% of above-ground biomass. Defoliation levels were calibrated by clipping a sample of potted plants at estimated levels and comparing their weights with weights of grass clipped to the soil surface. Plants clipped twice were re-clipped at the same level 14 days after the initial clipping, and plants clipped 3 times were re-clipped at the same level 14 and 28 days after the initial clipping.

After initial defoliation treatments, spotted knapweed seeds were evenly broadcast onto the soil surface. Seeds were collected in 1988 from Deer Lodge County, Mont. Seeding rate was 5,000 $m^{-2}$ (16 seeds per pot) which is within the range of spotted knapweed seed production on rangeland in Washington and Idaho (Schirman 1981). Four pots without Idaho fescue plants (bare ground) were also seeded. Pots were placed in a growth chamber with 12°C day and 8°C night temperatures and a 12-hour photoperiod at 200 uE $m^{-2}$ $s^{-1}$ intensity.

Watering treatments were initiated after spotted knapweed was seeded. Two complete replicates of defoliation, frequency and bare ground treatments were watered with 50 ml on Mondays, Wednesdays, and Fridays, and another pair of replicates were watered with 150 ml on Monday only.

### Soil Water Content

Volumetric soil water content ($cm^3$ $cm^{-3}$) was measured gravimetrically. After seeding with spotted knapweed, pots were saturated with water and allowed to drain to pot capacity, and weighed. Pots were re-weighed (total pot weight) weekly throughout the duration of the experiment. At harvest, soil volume and weights of all plant material, pots, and dried soil were determined. Soil water weight was calculated by subtracting the sum of the dried soil, plant, and pot weights from the total pot weight. Soil water weight was converted to volumetric water content by dividing by soil volume. Soil water contents of each treatment were averaged over the duration of the experiment and used in the analysis.

### Sampling

After 50 days of growth, all plant material was harvested. Soil plugs were pulled from the pots, soil volume determined, and the soil was washed from the roots. Soil was dried at 60°C to a constant weight and weighed. Spotted knapweed seedlings were counted, their roots were separated from those of Idaho fescue, and spotted knapweed shoots were separated from their roots. Spotted knapweed leaf areas were measured using a Li-Cor leaf area meter. Shoots were dried at 60°C to a constant weight and weighed. Root length was measured using a Comair root-length scanner, then roots were dried at 60°C to a constant weight and weighed. Idaho fescue plants were harvested as described for spotted knapweed above. Leaves were separated from roots, leaf areas measured, and the leaves were dried and weighed. Roots were also dried and weighed, but not measured for root length.

### Data Analysis

Data from the 2 experimental repeats were analyzed for homogeneity of variance using Pearson's chi-square test (SAS 1988). Variances were homogeneous and data were combined and analyzed using multiple linear regression (least squares) and analysis of variance. Regression models were used to predict average soil water content, spotted knapweed number, shoot weight, root weight, leaf area, and root length. Those models used Idaho fescue shoot weight or leaf area as independent variables. Regression models predicting spotted knapweed number and total weight used average soil water content as the independent variable. Models using defoliation level, defoliation frequency, frequency of watering, and their interactions as independent variables did not fit linear or curvilinear models. Those data were analyzed using analysis of variance. Main effects were defoliation level, defoliation frequency, and frequency of watering. Interactions included defoliation level by defoliation frequency, defoliation level by frequency of watering, defoliation frequency by frequency of watering, and defoliation level by defoliation frequency by frequency of watering.

## Results and Discussion

### Idaho Fescue Response

Defoliation level and frequency interacted to affect both Idaho fescue final shoot weight and leaf area (Fig. 1). When clipped once, there was no difference between 0 and 30% defoliation, and Idaho fescue progressively produced less final shoot weight and leaf area at 60 and 90% than at lower defoliation levels. When clipped 2 or 3 times, final shoot weights and leaf areas were reduced with each increase in defoliation level. Three defoliations had a greater impact on Idaho fescue than 1 or 2 defoliations at 30 and 60%. Ninety percent defoliation clipped 2 times produced similar final shoot weights and leaf areas to 90% clipped 3 times. These results are consistent with defoliated bluebunch wheatgrass (Mueggler, 1972), crested wheatgrass (*Agropyron desertorum* [Fisch.] Schult.)(Cooke et. al., 1958), and tall wheatgrass (*Agropyron elongatum* [Host] Beauv. 'Jose') (Undersander and Naylor, 1987).

Idaho fescue root weights were not affected by defoliation ($P>0.1$). In addition, watering frequency had no effect on Idaho fescue shoot weight, leaf area, or root growth ($P>0.1$). Similarly, Caldwell et al. (1981) found that shoot growth, but not root growth, of bluebunch wheatgrass was reduced by defoliation.

### Average Soil Water Content

Linear regression showed soil water content was negatively related to final Idaho fescue leaf area and shoot weight (Fig. 2). Regression models using Idaho fescue root weight were not significant. We assume lower leaf areas reduced transpiration (Kramer and Boyer 1995). These results indicate grass defoliation, and potentially grazing, will leave soil water available to neighboring plants.

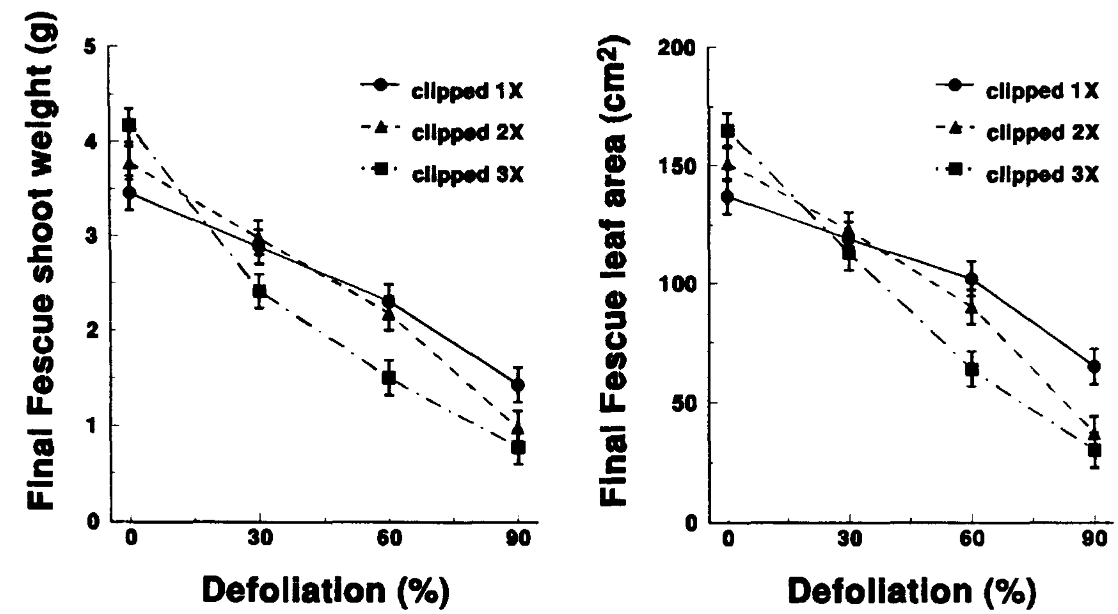


**Fig. 1. Effect of defoliation level and frequency on Idaho fescue shoot weight (g) and leaf area ($cm^2$)[1]. [1] Error bars represent ± 1SE.**

### Spotted Knapweed Emergence and Growth

Defoliation level and frequency interacted to affect spotted knapweed seedling numbers (Fig. 3). When Idaho fescue plants were clipped once, only those clipped at 90% had more spotted knapweed seedlings than the other defoliation levels, which responded similarly. Idaho fescue plants clipped twice produced similar spotted knapweed numbers as those clipped 3 times. At these defoliation frequencies, spotted knapweed numbers increased at each defoliation level. Spotted knapweed numbers after grass defoliation at 60%, clipped 2 or 3 times, were similar to those after a single defoliation at 90%.

There was also an interaction between defoliation level and watering frequency on spotted knapweed seedling numbers (P=0.08, Fig. 3). Idaho fescue defoliation levels of 60 and 90% had more spotted knapweed seedlings when watered 3 times per week than when watered once per week. Sheley and Larson (1996) suggested that knapweeds are able to capitalize on frequent but minimal periods of precipitation characteristic of arid

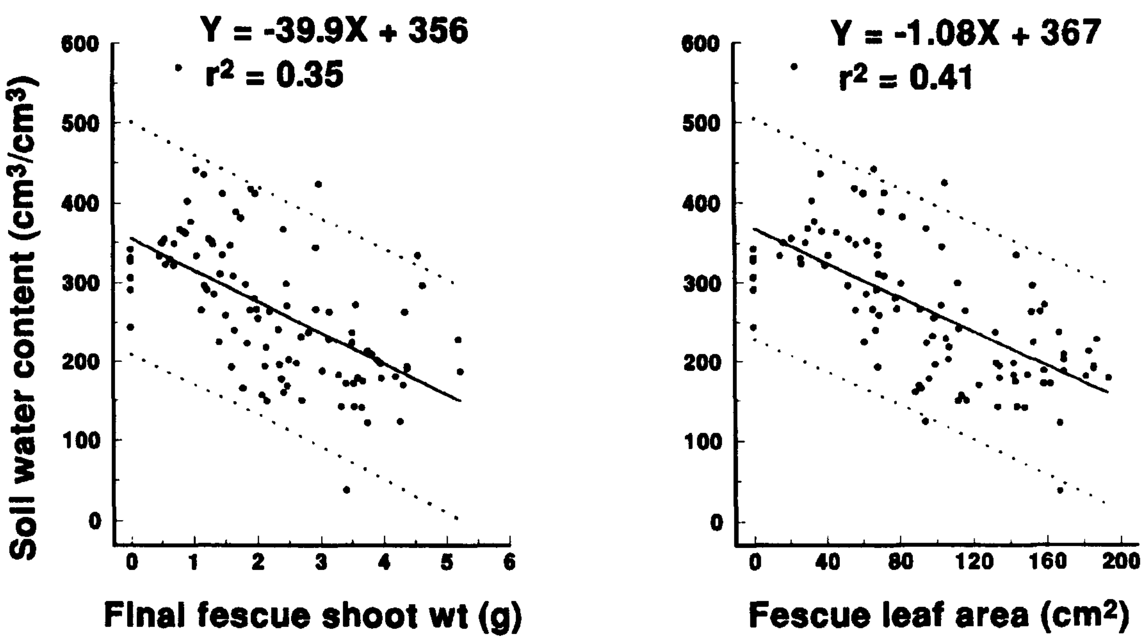


**Fig. 2. Relationship between soil water content ($cm^3$ $cm^{-3}$) and Idaho fescue shoot weight (g) and leaf area ($cm^2$). Dashed lines are 95% confidence intervals.**

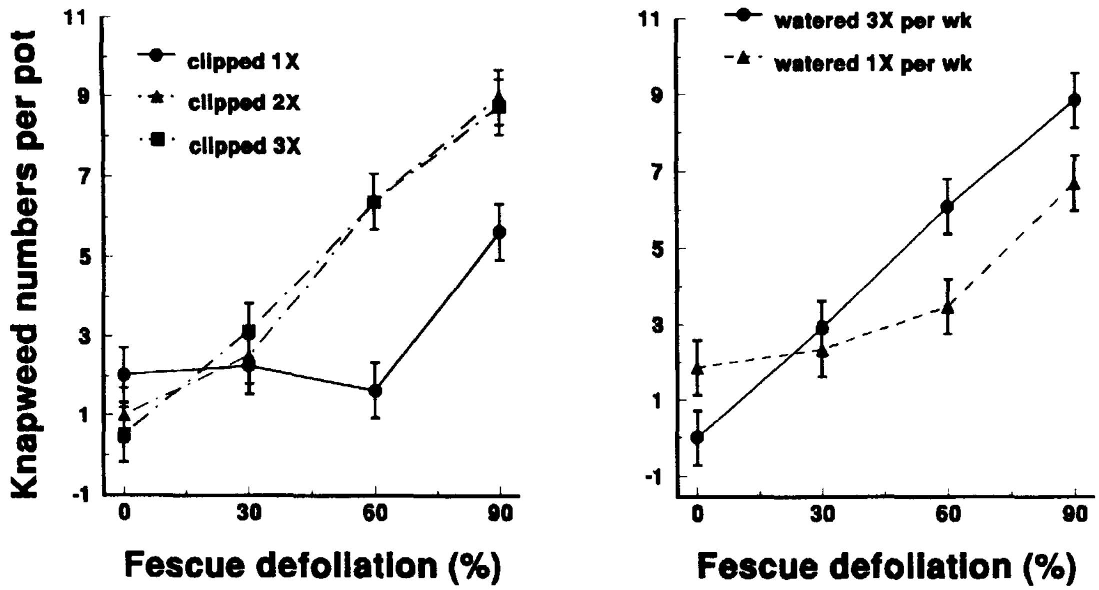


**Fig. 3. Effect of defoliation level and frequency, and defoliation level and watering frequency on spotted knapweed number per pot[1]. [1] Error bars represent ± 1SE.**

lands. This allows them to occupy and control safe sites as they become available. Our results indicate that severe defoliation together with frequent precipitation opens niches for spotted knapweed germination and emergence.

Defoliation level, defoliation frequency and frequency of watering did not interact to affect spotted knapweed growth, however main effects were significant. Increasing defoliation level of Idaho fescue caused an increase in spotted knapweed growth. Spotted knapweed growth in pots with grass clipped at 30% or more was greater than in pots with unclipped grass (Table 1). Grass defoliation greater than 60% produced greater spotted knapweed growth than lower defoliation levels. Sheley et al. (1997) found crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and bluebunch wheatgrass defoliation greater than 60% increased diffuse knapweed weight. Kennett et al. (1992), found that root crown and foliage growth of spotted knapweed were limited by competition from bluebunch wheatgrass. Our results indicate that even moderate defoliation (30%) may allow greater spotted knapweed growth on Idaho fescue rangeland.

**Table 1. Spotted knapweed growth parameters at 4 Idaho fescue defoliation levels (%).**

| Defoliation | Total weight | Shoot weight | Leaf area | Root weight | Root length |
|---|---|---|---|---|---|
| (%) | (g) | (g) | ($cm^2$) | (g) | (m) |
| 0 | 0.53 | 0.5 | 0.008 | 0.04 | 1.5 |
| 30 | 1.60 | 1.45 | 0.023 | 0.15 | 15.7 |
| 60 | 1.85 | 1.64 | 0.031 | 0.21 | 20.3 |
| 90 | 2.85 | 2.28 | 0.041 | 0.57 | 23.9 |
| SE[1] | 0.22 | 0.20 | 0.003 | 0.06 | 3.7 |

[1]Standard error of least squares means.

Increased clipping frequency also increased spotted knapweed weight, root length and leaf area (Table 2). Clipping more than once allowed greater spotted knapweed growth than a single clipping. However, clipping twice had a similar effect on spotted knapweed weight as clipping 3 times. Increasing grazing frequency may increase spotted knapweed invasion on Idaho fescue dominated rangeland.

**Table 2. Spotted knapweed growth parameters at 3 Idaho fescue defoliation frequencies (number of defoliations).**

| Defoliation | Total weight | Shoot weight | Leaf area | Root weight | Root length |
|---|---|---|---|---|---|
| Frequency | (g) | (g) | ($cm^2$) | (g) | (m) |
| 1 | 1.09 | 0.95 | 0.019 | 0.13 | 15.2 |
| 2 | 1.87 | 1.60 | 0.028 | 0.28 | 14.2 |
| 3 | 2.17 | 1.85 | 0.030 | 0.31 | 16.7 |
| SE[1] | 0.19 | 0.17 | 0.003 | 0.05 | 3.2 |

[1]Standard error of least squares means.

Spotted knapweed root weights and leaf areas were greater in pots watered 3 times per week than pots watered once per week (Table 3). Watering did not affect Idaho fescue plants, suggesting watering once per week was sufficient to maintain fescue growth, but was limiting for spotted knapweed seedling growth.

Regressions showed spotted knapweed numbers and total weight increased in pots where Idaho fescue clipping resulted in

**Table 3. Spotted knapweed growth parameters at 2 watering frequencies (number of waterings per week).**

| Defoliation | Total weight | Shoot weight | Leaf area | Root weight | Root length |
|---|---|---|---|---|---|
| Frequency | (g) | (g) | ($cm^2$) | (g) | (m) |
| 1 | 1.50 | 1.32 | 0.022 | 0.18 | 12.5 |
| 3 | 1.92 | 1.62 | 0.030 | 0.30 | 18.2 |
| SE[1] | 0.15 | 0.14 | 0.002 | 0.04 | 2.59 |

[1]Standard error of least squares means.

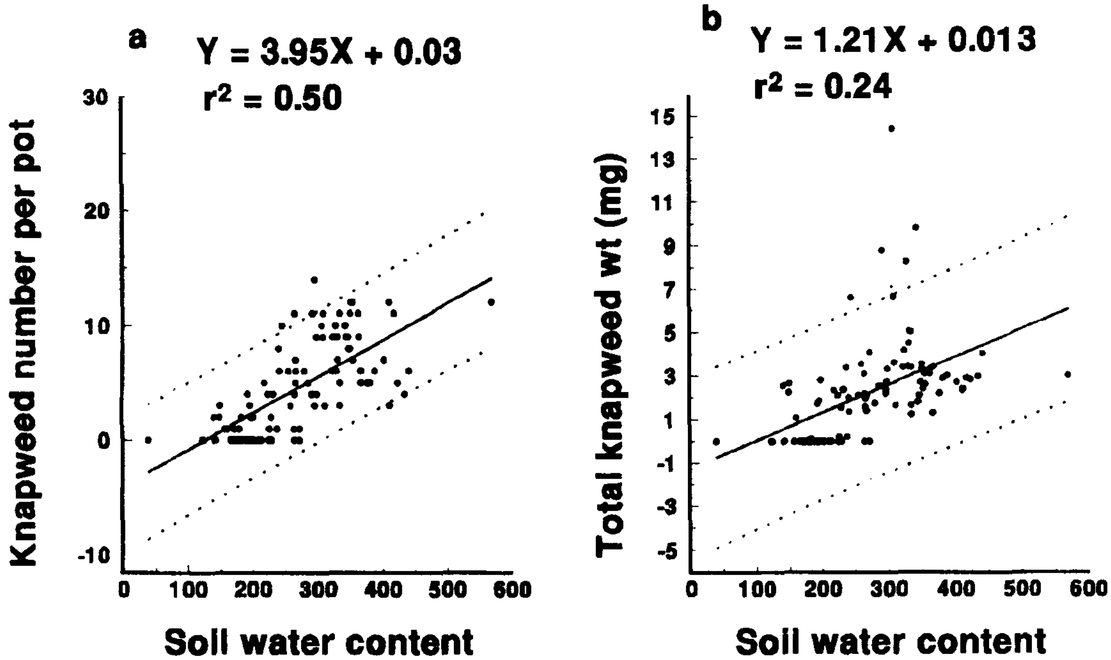


**Fig. 4. Relationship between spotted knapweed number per pot or total weight and soil water content ($cm^3$ $cm^{-3}$). Dashed lines are 95% confidence intervals.**

higher soil water content (Fig. 4). $R^2$ values indicate soil water content had a greater effect on seedling emergence than seedling growth. Thus, other factors, such as shading, influenced spotted knapweed growth.

Increasing both defoliation level and frequency on Idaho fescue plants caused the soil water content to increase, resulting in a corresponding increase in spotted knapweed emergence and growth. These results suggest that moderate intensity and infrequent grazing can minimize spotted knapweed invasion by maximizing soil water use by Idaho fescue.

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