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Influence of Spotted Knapweed (*Centaurea maculosa*) on Surface Runoff and Sediment Yield¹

JOHN R. LACEY, CLAYTON B. MARLOW, and JOHN R. LANE²

Abstract. The influence of spotted knapweed on surface runoff and sediment yield was determined under simulated rainfall conditions near Garrison, MT. Comparisons were made in 12 paired plots: one of each pair dominated by bunchgrass and the other dominated by spotted knapweed. Runoff and sediment yield were 56% and 192% higher, respectively, for the spotted knapweed, rather than the bunchgrass vegetation types. Spotted knapweed invasion onto bunchgrass range of western Montana is thus detrimental to the protection of soil and water resources. **Nomenclature:** Spotted knapweed, *Centaurea maculosa* Lam. #³ CENMA.

Additional index words: Erosion, CENMA.

INTRODUCTION

Spotted knapweed was introduced into the Pacific Northwest from Eurasia around 1900 (10). Although described as a pioneer species that thrives on dry disturbed sites (11), spotted knapweed has invaded over 1.8 million ha of range and pastureland in Montana (5). It is recognized as an aggressive invader of range and pasture in the Northern Intermountain Region (4, 5, 7, 8).

Most of the land dominated by spotted knapweed occurs on range that formerly produced bluebunch wheatgrass [*Agropyron spicatum* (Pursh.) Scribn. and Smith] and/or rough fescue (*Festuca scabrella* Torr. in Hook). As higher successional grasses are replaced by lower successional forbs, runoff normally increases (2). Because initial observations indicated more bare ground and less litter under spotted knapweed than in bunchgrass communities, more runoff was expected on the knapweed-dominated sites. This report provides an evaluation of the influence of spotted knapweed on surface runoff and sediment yield under simulated rainfall conditions.

MATERIALS AND METHODS

A modified rainfall simulator was used to apply a controlled volume of rainfall to 24 65- by 65-cm plots

(Figure 1) (6). Rainfall was applied during two consecutive 30-min periods. Resultant surface runoff was collected and measured at 1-min intervals for the first 5 min and then at 5-min intervals until the 30-min run was completed. Runoff collections were oven dried at 100 C for 24 h to remove water. Soil material was weighed, and sediment yield calculated.

Data were collected from 12 study sites during November, 1987. Within each study site, paired plots were located subjectively to minimize soil and topographic differences and to maximize vegetation differences. Bunchgrasses contributed about 90% of the herbage production on one plot of each pair, while spotted knapweed contributed about 90% of the production on the other.

The study was conducted 8 km northwest of Garrison, MT. Annual precipitation averages 33 cm, and elevation averages 1372 m. The soils were Doney-Dolus Channery loams (fine-loamy, mixed frigid, Typic Ustochrepts, and loamy-skeletal, mixed, Aridic Haploborolls). Slopes ranged from 13 to 37%. Vegetation was mostly bluebunch wheatgrass, spotted knapweed, rough fescue, prairie junegrass (*Koeleria cristata* L.), hoods phlox (*Phlox hoodii* Rich.), Idaho fescue [*Festuca idahoensis* (Elmer) Pers.], and lupine (*Lupinus* spp.).

The area was lightly grazed by cattle in the spring of 1987 and rested during summer and fall. Based on plant form and resistance to weathering, maximum differences in ground cover between grass-dominated, and spotted knapweed-dominated communities were expected to occur from October through May. Runoff from rainfall is frequent in fall and spring, while snow-melt normally occurs during winter and spring.

Foliar cover of grasses and forbs, and percentage of

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³Letters following this symbol are a WSSA-approved computer code from composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.



Figure 1. A modified rainfall simulator was used to apply rainfall. The simulator was elevated on a 1.5-m stand to achieve sufficient raindrop impact.

ground covered by litter and rock (>0.32 cm diam) were estimated visually on each plot. A clinometer was used to determine percent slope of each plot. Soil moisture at 0- to 2.5-cm depth was determined gravimetrically from areas adjacent to each plot.

An initial 30-min simulated rainfall was conducted on the unaltered site to measure the effect of vegetation cover plus soil surface characteristics on surface runoff and sediment yield. Vegetation was then clipped to a 0.85-cm height, and a second 30-min simulated rainfall was conducted to measure the effect of soil surface characteristics alone on surface runoff and sediment yield. Vegetation (standing dead and live matter) clipped from each plot was separated into four categories (perennial grasses, annual grasses, spotted knapweed, and other forbs), was oven dried at 65 C, and was weighed.

Although individual plots of each pair received similar quantities of rainfall, rate of rainfall varied between pairs from 2.5 to 7.6 cm/h. Variation in the rate was attributed to changes in air temperature and barometric pressure. These factors affected water flow within the rainfall simulator during data collection periods. This amount of rainfall represents about 48% of expected storm intensities in climates similar to the study area (1).

Comparative runoff, infiltration rate, and sediment yield data between grass-dominated and spotted knapweed-dominated plots were analyzed in a paired T-test. The bias that resulted from applying different volumes of water to the paired plots was eliminated by using a covariate analysis. Multiple regression analyses were used to measure effects of various site characteristics on runoff and sediment production. Level of significance was set at 0.10 for all statistical analyses.

The general regression model was:

$$\text{surface runoff or sediment production} = f(x_i);$$

$i = 1$ to 13 where the dependent variables (runoff or sediment) were hypothesized to be a linear function of 13 independent variables: foliar cover, litter, small rock, bare ground, perennial grass, annual grass, foliar cover plus litter, spotted knapweed, other forb, total vegetation, soil moisture, slope, and water applied. Statistical significance (T-test) was used to determine which explanatory variables should be retained in the regression model. Many of the independent variables were eliminated because they had no measurable effect on runoff or sediment yield.

RESULTS AND DISCUSSION

Surface runoff from the initial 30-min simulated rainfall on grass-dominated sites varied from 3 to 49% of the total volume applied. Runoff averaged 23% on these 12 sites (Table 1) and was less ($P < 0.10$) than runoff from the sites dominated by spotted knapweed. Runoff from the initial 30-min simulated rainfall on spotted knapweed sites averaged 36% and varied from 1 to 67% of the total volume applied.

Surface runoff from the second 30-min simulated rainfall on grass-dominated sites varied from 16 to 66% and averaged 39% of the total volume applied (Table

Table 1. Surface runoff and sediment yield on 12 grass-dominated and 12 spotted knapweed-dominated plots subjected to two consecutive 30-min simulated rainfall periods in November, 1987. The initial 30-min period was on the unaltered site to measure the effect of vegetative cover plus soil surface characteristics, and vegetative cover was removed before the second 30-min period to measure the effects of surface characteristics alone.

Site characteristics ^a	First 30-min.		Second 30-min.	
	Grass	Spotted knapweed	Grass	Spotted knapweed
Surface runoff (%)	23	36*	39	45
Sediment yield (kg/ha)	44	128*	95	161

^aAn asterisk indicates significance, $P < 0.10$, as compared with paired T-test.

1). Runoff on the spotted knapweed-dominated sites did not differ ($P > 0.10$) from bunchgrass sites and varied from 8 to 70% with an average of 45% of the total volume applied.

Surface runoff per 5 min interval was consistently higher on sites dominated by spotted knapweed rather than bunchgrasses (Figure 2). Regardless of vegetation, the amount of runoff per 5-min interval would increase two- to three-fold during the respective 30-min sampling periods.

Sediment yield on the spotted knapweed-dominated sites varied from 1 to 787 kg/ha during the initial 30-min rain and averaged 128 kg/ha (Table 1). This was higher ($P < 0.10$) than sediment yield (44 kg/ha) from grass-dominated sites. Sediment yield during the second 30-min run averaged 161 and 95 kg/ha, for the spotted knapweed and grass communities, respectively.

Percent slope, bare ground, and ground cover (foliar cover plus plant litter) were the single characteristics most highly related ($P < 0.10$) to sediment yield during the initial 30-min application. Multiple regression analyses indicated that 45% of the variation ($P < 0.10$) associated with sediment yield was explained by the interaction of ground cover, slope, and volume of water applied.

The regression equation indicated:

$$\begin{aligned} \text{Sediment yield (kg/ha)} = & -52 \\ & - 4 (\text{ground cover \%}) + 9 (\text{slope \%}) \\ & + 99 (1.90 \text{ cm simulated rain applied}). \end{aligned}$$

This suggests that for each additional percent of ground cover on the site, sediment yield decreased by 4 kg/ha; for each additional percent of slope, sediment yield increased by 9 kg/ha; and, for each additional 1.9 cm of

Table 2. Site characteristics of 12 grass-dominated and 12 spotted knapweed-dominated plots before simulated rainfall in November 1987.

Site characteristics	Vegetation type ^a	
	Grass	Spotted knapweed
Foliar cover (%)	60 (12)	52 (16)
Litter (%)	9 (4)	12 (8)
Small rock (%)	12 (8)	13 (8)
Bare ground (%)	20 (13)	24 (16)
Perennial grass (kg/ha)	1345 (903)	147 (98)
Annual grass (kg/ha)	1 (3)	10 (67)
Spotted knapweed (kg/ha)	4 (7)	966 (457)
Other forbs (kg/ha)	169 (192)	70 (87)
Total vegetation (kg/ha)	1520 (913)	1193 (434)
Soil moisture (%)	7 (3)	7 (3)
Slope gradient (%)	24 (8)	24 (8)

^aStandard deviation is indicated within parentheses.

rain applied, sediment yield increased by 99 kg/ha. Each of the independent variables was significant ($P < 0.10$). After the vegetation was removed (second 30-min simulated rainfall period), sediment yields were similar between the sites that produced bunchgrasses and those that produced spotted knapweed (Table 1).

Runoff was more difficult to predict than sediment yield. Although 31% of the variation in runoff was explained by the interaction of ground cover, slope, and amount of water applied, slope was the only significant factor ($P < 0.10$) in predicting surface runoff.

Soil moisture before simulated rainfall varied from 4 to 12% and averaged 7% (Table 2). Simple linear regression indicated it was not correlated to surface runoff ($P > 0.10$) or sediment yield ($P > 0.10$). Including soil moisture before simulated rainfall in the multiple regression with foliar cover, slope, and water applied did not improve the equation's predictive value.

Perennial grass production varied from 556 to 3805 kg/ha on the bunchgrass sites and averaged 1345 kg/ha (Table 2). This represented 89% of the total vegetation. Spotted knapweed production on knapweed-dominated sites varied from 580 to 2276 kg/ha and averaged 966 kg/ha. This represented 81% of the total vegetation (1193 kg/ha). Total vegetation weight ($P > 0.10$) was not a useful variable for predicting surface runoff or sediment yield.

The poor correlation between total vegetation weight and runoff may have been influenced by the amount of bare ground which averaged 20 and 24% respectively, on the grass- and spotted knapweed-dominated plots. Bare ground was correlated ($R^2 = 0.25$) with sediment yield ($P < 0.10$) and with surface runoff ($R^2 = 0.13$)

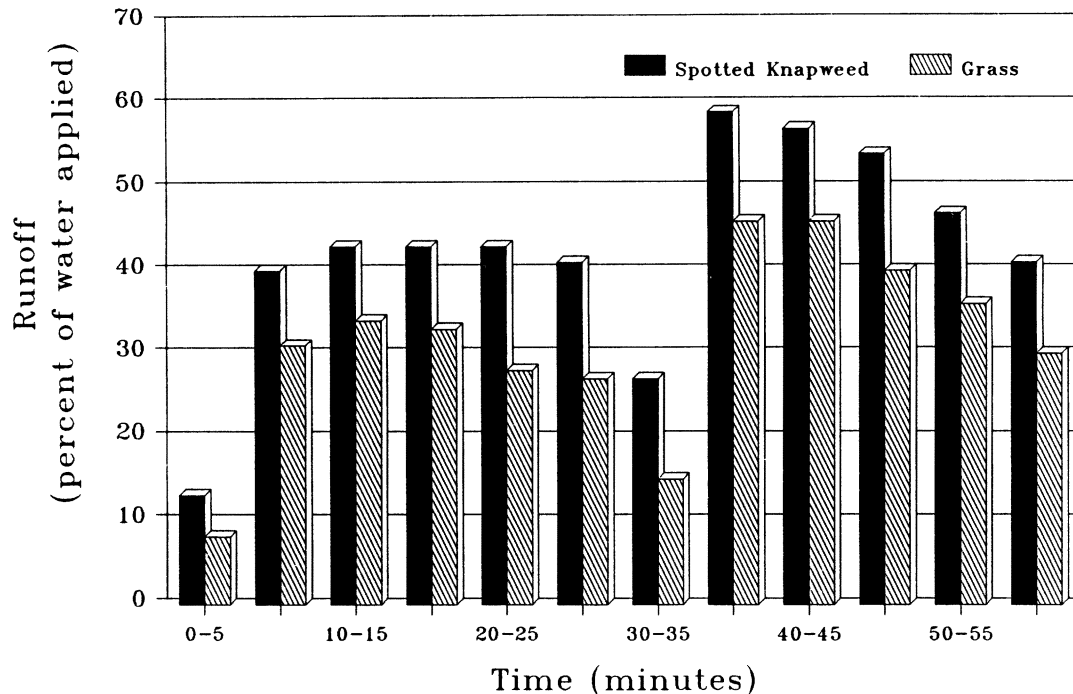


Figure 2. Surface runoff from 12 grass-dominated and 12 spotted knapweed-dominated plots at various time intervals during two consecutive 30-min simulated rainfall periods in November, 1987. The initial 30-min period was on the unaltered site to measure the effect of vegetation cover plus soil surface characteristics. Vegetative cover was removed before the second 30-min period to measure the effects of surface characteristics alone.

($P < 0.10$). Correlation might have been higher if the size of maximum bare openings within the vegetation canopy had been considered (9).

Bunchgrass plots had higher average infiltration rates than spotted knapweed plots. This difference was most apparent during the 20- to 30-min period. After the vegetation was clipped and removed (second 30-min period), infiltration rates did not differ ($P > 0.10$) between the sites that had produced a crop of bunchgrasses and those that had produced spotted knapweed. Thus, grass-dominated vegetation protects the soil surface better and allows more infiltration and less runoff than does spotted knapweed-dominated vegetation. The virtues of grass for the conservation of soil and water were observed in earlier studies (3).

Surface runoff and interrill erosion are greater from spotted knapweed-dominated sites than from similar bunchgrass-dominated sites. Spotted knapweed invasion onto bunchgrass range is detrimental to the objectives of protecting topsoil and limiting sedimentation of reservoirs and water sources. Thus, environmental concern is justification to reduce infestations of spotted knapweed.

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