Nutrient Composition of Spotted Knapweed (*Centaurea maculosa*)

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Abstract

Spotted knapweed (*Centaurea maculosa* Lam.) is a noxious plant that has invaded many native ranges and open woodlands of western Montana. Knapweed is generally considered to have a low palatability to domestic livestock and wildlife, but local ranchers have observed sheep, goats, and some cattle ingesting large quantities of fresh knapweed during the spring and knapweed silage and hay during the winter. Nutrient analysis of plants collected prior to flowering showed neutral detergent fiber at 24.2 to 53.0% (dry wt.), ether extract 3.1 to 9.0%, crude protein 6.2 to 18.2%, total nonstructural carbohydrates 11.0 to 27.5%, ash 4.9 to 9.3%, in vitro dry matter digestibility 53.2 to 61.8%, and gross energy 4,088 to 4,539 cal/g. Crude protein and nonstructural carbohydrates were most concentrated during the spring growth period when stems were developing. As the stems matured during summer they became more fibrous resulting in lower protein and carbohydrate levels. Just prior to flowering, tall plants with stems approaching 1 m had significantly higher fiber, but lower ether extract, carbohydrates, and in vitro dry matter digestibility than plants with stems less than 0.5 m. Crude protein, ash, and gross energy were the same for both groups. It was concluded that spotted knapweed does have some nutritional value as a livestock forage. Spring grazing of knapweed or harvesting for a winter forage may be useful in the control of this noxious plant.

Key words: *Centaurea maculosa* Lam., weed control, noxious plants, neutral detergent fiber, crude protein, total nonstructural carbohydrates, in vitro digestibility.

Spotted knapweed (*Centaurea maculosa* Lam.) is a Eurasian native found in most northern U.S. states and provinces of Canada (Reed and Hughes 1970, Moore 1972, Watson and Renney 1974). Introduced to the Pacific Northwest region around the turn of the century, Maddox (1979) estimated 842,000 ha of spotted knapweed in the 3 states of Montana, Idaho, and Washington. Over 800,000 ha occur in western Montana and it is spreading at an annual rate of approximately 27.4% (Lacey 1983). Initially considered only a rangeland problem, it is aggressively penetrating openings in forest habitats (Spoon et al. 1983).

As the density of knapweed increases, the productivity of the desirable forage plants decreases drastically, 40–80% or greater (Watson and Renney 1974, Harris and Cranston 1979, Maddox 1979). Annual revenue losses in Montana from the current level of infestation are estimated at $4.5 million (French and Lacey 1983). On forested land the infestation is beginning to affect the growth and survival of shrubs and young trees (Spoon et al. 1983). Dense stands lower the recreational quality of a site and they detract from the aesthetics, particularly along forest roads and trails.

Livestock consumption of spotted knapweed has been considered minimal, especially mature plants because of their high fiber content and low nutritive value (Watson and Renney 1974, Maddox 1979, Strang et al. 1979). In 1983, Cox reported sheep eating large quantities of knapweed in the spring and early summer when the plants are succulent and actively growing. Not only did sheep eat it, but they preferentially selected the knapweed over grasses as long as the knapweed was abundant. Spoon et al. (1979) concluded that sheep prefer knapweed and that goats eat it along with other forage. They also reported significant early/mid season use by some cattle in western Montana. This raised questions about knapweed's nutritional content. In this paper we report selected nutrient components of spotted knapweed from populations in western Montana.

Methods and Materials

1984 Plant Samples

In 1984 plant samples were collected from 4 sites in the vicinity of Missoula, Mont. All were within Township 13 North and Range 19 West. Site 1 was sampled on 31 May and 2 August. This population was located on a vacant lot surrounded by commercial property. The soil surface had an abundance of sawdust and woody residue. Plants were large with mature stems reaching 1.0–1.5 m in height. Because of slower growth, sites 2, 3, and 4 were sampled initially on 12 June and again on 2 August. These were more typical of rangeland populations with mature stem heights ranging from 0.2 to 0.8 m. Samples were sealed in plastic bags, and placed on ice for transport to the laboratory. Two different samples were collected at site 1 during August: regrowth from plants that had been mowed earlier in the year for silage and mature plants that had received no previous treatment.

Solvent Extraction

Fresh tissues from May/June collections were treated as follows. Moisture content was measured in triplicate subsamples by oven drying at 100° C. Three fresh samples, 50 g each, were extracted with 500 ml of solvent; the first was extracted with chloroform for 5 minutes, the second with 95% ethanol for 30 min, and the third with distilled water overnight (15 hr). They were air-dried after extraction.

Several hundred grams of fresh tissue was placed in a 100° C oven for 10 min to stop metabolic activity, then air-dried. Three air-dried samples from each site, with a dry weight equivalent to 50 g of fresh tissue, were extracted like the fresh samples. A dried sample from each population was used as an unextracted control. All samples were ground to particle sizes specified for analysis, oven-dried (65° C), and sealed in screw cap vials until needed.

Silage and Hay

Approximately 180 kg of knapweed were cut with a mower at a site 1 on 31 May and again on 13 June 1984. The chopped tissue was packed into plastic bags and tightly sealed for ensilaging. On 2 August a sample of each silage was air-dried and prepared like the other samples for analysis. Knapweed hay was obtained from a local rancher who had cut and baled the plants during the first 2 weeks in August 1984. Random samples from 6 bales were ground and mixed into a single sample.

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1985 Plant Samples

Between 28 June and 2 July plant samples were collected from 2 separate populations at each of 7 locations in western Montana (Somers, Polson, Missoula, Stevensville, Darby, Drummond, Superior). The first 5 sites were located along a north/south line approximately 175 miles long. Superior and Drummond were 50 miles west and east of this line, respectively. The 2 populations at each location were selected by plant height, one representing tall plants with stems approaching 1 m and the other representing short plants with stems less than 0.5 m. In general the tall plants were growing on sites that had been rangeland, dry pasture, or grazeable woodlands, but where the soils had been severely disturbed by man and his activities, along the edge of gravel roads, and open lots associated with, or influenced by, commercial development. Short plants grew on rangelands and dry pasture where soils appeared less disturbed and possibly more harsh, hotter, drier, or with fewer nutrients in the soil. At each population 30 stems were measured for length; the nearest stem was measured every 30 cm along a 9-m line transect. For nutrient analysis 1 or more stems were clipped near ground level every 1.5 m along this same tape. In the short plant populations it was necessary to cut numerous plants at each point in order to obtain sufficient tissue. These stems were combined in a plastic bag and returned on ice to the laboratory. All plants were rinsed with cold water to remove loose dust, then clipped into small pieces and placed into a 100° C oven for 45 min. The tissue was transferred into paper bags to oven dry (65° C). After grinding and redrying (65° C for 24 hr), samples were sealed in screw cap vials and stored in a desiccator until needed.

Chemical Analysis

The nutrient analysis included crude protein (% nitrogen by microKjeldahl × 6.25), ether extract (4 hours extraction instead of 16), ash, and gross energy as described by Harris (1970), neutral detergent fiber (Goering and Van Soest 1970), and total nonstructural carbohydrates (daSilveira et al. 1978). Each composite sample was analyzed in duplicate. For mineral analysis 0.5 g of 60 mesh tissue was ashed (500° C for 2.5 hr). After cooling, the ash was moistened with deionized water, covered with 10 ml of aqueous HCl (1:1), and gently boiled to reduce the volume about one-half. This was diluted to 50 ml and analyzed by inductively coupled plasma spectroscopy using a Jarrell-Ash AtomComp Model 865. Dry matter digestibility was determined in triplicate using Barnes modification of the Tilley and Terry technique (Harris 1970). Cnicin, a bitter tasting sesquiterpene lactone located in glandular trichomes on the epidermal surface of spotted knapweed, was quantified by high performance liquid chromatography (Marchand et al. 1983, Locken and Kelsey in press).

Data Analysis

Data for spring vs. summer plants in 1984 and tall vs. short plants in 1985 were analyzed by a one-way analysis of variance. Prior to analysis the percentage data were transformed to get homogeneity in variances.

Results

In the spring of 1984 when the stems of spotted knapweed were succulent and actively growing, the nutrient content of this tissue was comparable to native forage plants and appears adequate to meet livestock needs (Table 1) (Ensminger and Olentine 1978). Plants from the 3 upland sites had 9–10% crude protein compared to 18.2% at site 1. Woody organic matter on the soil surface was apparently supplying nutrients for the latter. All of the other components were quite similar between the 4 populations. By early August, approximately 2 to 3 weeks after the onset of flowering, the fiber content had nearly doubled, causing decreases in all the other components, particularly the crude protein (Table 1). The ether extract was least affected, with increases at 2 sites. Gross energy was higher for all plants in the summer. Regrowth from plants cut in May/June for silage was less fibrous and had lower cnicin concentrations compared to those left untreated. Protein and carbohydrates were slightly higher in the regrowth while ash and ether extractables were similar to the quantities in untreated plants.

Solvent extractions had essentially the same effect on fresh and dried samples; therefore, only the data for dried tissues are presented in Table 2. Chloroform and ethanol gave nearly identical results; they removed 50% or more of the ether extractables and 74 to 90% of the cnicin, with almost no change in any of the other substituents (Tables 1 and 2). Chloroform was more efficient at removing cnicin. Water extracted soluble minerals and carbohydrates, concentrating all of the other components in the tissue.

Spring knapweed plants and the silage from site 1 had a chemical composition comparable to alfalfa silage and hay (Tables 1 and 3). The knapweed hay was very stemmy and fibrous, with a low

Table 1. Nutrient composition and cnicin concentrations of spotted knapweed collected at 4 sites in the Missoula valley during the spring and summer of 1984.

	% Dry Weight							
Sample description	Neutral detergent fiber	Ether extract	Crude protein	Total nonstructural carbohydrates	Ash	Cnicin	Other	Gross energy (cal/g)
Site 1								
May	24.2	3.1	18.2	24.9	9.3	0.53	19.8	4093
Aug. untreated	50.7	3.7	9.4	16.7	5.2	0.68	13.6	4436
Aug. regrowth	33.3	3.4	13.4	18.7	5.7	0.41	25.1	4362
Sites 2–4								
June	26.7	5.7	9.2	25.4	7.7	1.18	24.1	4195
	(0.6)[1]	(1.8)	(0.4)	(1.8)	(0.5)	(0.54)	(2.5)	(61)
Aug.	45.5	4.3	5.2	19.0	5.2	0.54	20.2	4332
	(4.9)	(1.0)	(0.4)	(1.1)	(0.3)	(0.08)	(4.2)	(25)
Mean								
May/June	26.1a[2]	5.0a	11.5a	25.3a	8.1a	1.02a	23.0a	4170a
	(1.3)	(1.9)	(4.5)	(1.5)	(0.9)	(0.55)	(3.0)	(72)
Aug.	46.8b	4.2a	6.2a	18.5b	5.2b	0.58a	18.6a	4358b
	(4.8)	(0.8)	(2.1)	(1.5)	(0.2)	(0.09)	(4.7)	(56)

[1]Standard deviation.
[2]Means followed by the same letter are not significantly different at the 0.05 level of probability.

Table 2. Nutrient composition and cnicin concentrations for spotted knapweed collected in the spring of 1984 and subjected to various solvent extractions.

Sample treatment	% Dry Weight						
	Neutral detergent fiber	Ether extract	Crude protein	Total nonstructural carbohydrates	Ash	Cnicin	Other
5 min. $CHCl_3$							
Site 1	22.6	1.9	19.5	23.5	9.8	0.00[1]	22.7
Sites 2–4	28.8	2.1	9.1	25.0	8.0	0.13	26.9
	(0.8)	(0.2)	(0.8)	(2.4)	(0.7)	(0.08)	(2.3)
30 min. EtOH							
Site 1	24.2	1.9	19.4	23.1	9.6	0.11	21.7
Sites 2–4	28.6	2.6	9.4	25.7	8.1	0.30	25.3
	(1.8)	(0.3)	(0.7)	(0.6)	(0.6)	(0.17)	(1.4)
overnight H_2O							
Site 1	33.6	4.7	21.6	12.9	5.0	0.71	21.5
Sites 2–4	38.9	6.0	10.9	18.8	4.5	1.30	19.8
	(2.0)	(0.5)	(0.7)	(3.7)	(0.4)	(0.41)	(3.2)

[1]Below detection limit.

Table 3. Nutrient composition of spotted knapweed silage cut May and June, and knapweed hay cut Aug. 1984.

Sample treatment	% Dry Weight						
	Neutral detergent fiber	Ether extract	Crude protein	Total nonstructural carbohydrates	Ash	Cnicin	Other
May silage	23.4	4.9	19.6	9.3	10.2	0.20	32.4
June silage	30.0	3.5	16.5	11.2	8.7	0.32	29.8
Aug. hay	56.1	1.8	5.7	11.0	4.2	0.23	21.0
Alfalfa silage[1]	52.3	3.7	17.3	—	8.9	—	—
Alfalfa hay[1]	47.5	2.6	17.6	—	9.0	—	—

[1]Ensminger and Olentine 1978.

protein content. It should be noted that the objective for cutting these plants was to prevent seed dispersal and not to make hay, consequently it was cut after its nutritional prime. A higher quality hay could have been obtained by cutting earlier in the season.

In 1985 the knapweed plants were sampled in the bud stage just prior to flowering. Tall and short plants differed in their nutrient composition (Table 4). Tall plants contained significantly more fiber, but less ether extract, carbohydrates, and unknown or other substances. Crude protein did not differ between tall and short plants and there was no consistent trends for ash or gross energy. Tall plants had a slightly lower mineral content for all elements except K, with Ca, Al, and Si being significantly lower (Table 5). In vitro dry matter digestibility was acceptable at 56.6% when averaged for all populations. The tall plants were consistently less digestible (54.6%) than the short plants (58.5%). The 1985 samples had a composition similar to those in 1984.

Discussion

The forage value of spotted knapweed for livestock has been considered minimal because of poor nutritive quality and high fiber content (Watson and Renney 1974, Maddox 1979). Our analysis indicates that spotted knapweed is not lacking in nutritional quality during the spring, when livestock are most willing to graze it (Cox 1983, Spoon et al. 1983).

Table 4. Nutrient composition of tall and short spotted knapweed plants collected at 7 locations in western Montana during summer, 1985.

Plant size	Stem length (centimeters)		% Dry Weight							Gross energy (cal/g)
	Mean	Range	Neutral detergent fiber	Ether extract	Crude protein	TNC[1]	Ash	Other	Digestibility	
Tall	93a[2]	36–134	50.6a	4.6a	9.9a	13.1a	6.3a	15.4a	54.6a	4318a
	(12)[3]	(14)(15)	(2.2)	(1.4)	(1.8)	(1.7)	(0.8)	(2.5)	(1.0)	(109)
Short	22b	8– 43	36.1b	7.1b	8.6a	15.6b	6.6a	26.0b	58.5b	4369a
	(5)	(4) (9)	(3.6)	(1.2)	(2.3)	(0.8)	(1.0)	(4.3)	(2.2)	(92)
All	58	22– 89	43.3	5.9	9.2	14.4	6.5	20.7	56.6	4344
	(38)	(18)(49)	(8.0)	(1.8)	(2.1)	(1.8)	(0.9)	(6.5)	(2.6)	(100)

[1]Total nonstructural carbohydrates.
[2]Means followed by the same letter are not significantly different at the 0.05 level of probability.
[3]Standard deviation.

Table 5. The mineral composition of tall and short spotted knapweed plants collected at seven locations in western Montana during summer, 1985.

Plant size	% Dry Weight				Ppm[1]									
	Ca	Mg	P	K	Al	B	Cu	Fe	Mn	Mo	Si	Na	Ti	Zn
Tall	0.84a[2]	0.14a	0.17a	2.18a	92a	28.0a	7.0a	121.5a	19.1a	0.4a	318a	17a	4.0a	13.5a
	(0.17)[3]	(0.04)	(0.04)	(0.27)	(35)	(15.4)	(2.1)	(41.9)	(5.1)	(0.2)	(60)	(8)	(2.0)	(2.0)
Short	1.13b	0.18a	0.21a	1.88a	165b	29.7a	8.3a	183.4a	48.9a	1.2a	457b	25a	7.8a	15.9a
	(0.17)	(0.04)	(0.04)	(0.34)	(89)	(15.9)	(4.8)	(81.4)	(36.8)	(1.0)	(138)	(14)	(5.0)	(5.1)
All	0.99	0.16	0.19	2.03	128	28.8	7.6	152.5	34.0	0.8	388	21	5.9	14.7
	(0.22)	(0.04)	(0.04)	(0.34)	(75)	(15.1)	(3.6)	(70.0)	(29.6)	(0.8)	(125)	(12)	(4.2)	(3.9)

[1]Cd, Co, and Hg averaged less than 1.0 ppm in both tall and short plants.
[2]Means followed by the same letter are not significantly different at the 0.05 level of probability.
[3]Standard deviation.

Tall plants had significantly more fiber and less ether extract, nonstructural carbohydrates and miscellaneous components (Table 4). There was no difference between tall and short plants for crude protein, ash, or gross energy. Mineral content and digestibility were lower in the tall plants (Table 5), but the differences are of no major consequence.

The leaves of spotted knapweed contain the bitter tasting sesquiterpene lactone, cnicin, (Politis 1946a, Politis 1946b, Wagner 1977, Muir and Majak 1983, Locken and Kelsey in press, Kelsey and Locken 1987) that could decrease palatability relative to other plants. In the combined aerial tissues cnicin concentrations are lowest in the spring (0.5% dry wt.) and reach a maximum (1.0%) around flowering in July (Locken and Kelsey in press). Interestingly, the flower heads of knapweed contain only trace quantities of cnicin, and these structures are selectively eaten by most livestock and wildlife (Watson and Renney 1974, Spoon et all. 1983, Bucher 19j84). Bitter tasting lactones in other plant species inhibit feeding by mammalian herbivores (Burnett et al. 1977, 1978; Mabry and Gill 1979). Sesquiterpene lactones in Russian knapweed (*C. repens* L.) and yellow star thistle (*C. solstitialis* L.) are the suspected cause of equine nigropallidal encephalomalacia in horses that have ingested large quantities of these plants for prolonged periods (Cordy 1978, Stevens 1982, Stevens and Merrill 1985). To our knowledge there have been no reports of any livestock poisoning from spotted knapweed in Montana or Canada (Watson and Renney 1974).

Cnicin concentrations in fresh or dry spotted knapweed tissues can be greatly reduced by extraction for short periods with organic solvents without damaging the nutritional composition of the extracted residue (Tables 1 and 2). Water extraction removed carbohydrates and minerals, concentrating the cnicin, crude protein, and fiber in the residue. Ensilaging decreased the cnicin concentration by about 50% (Tables 1 and 3). Plants that had regrown after cutting also had a lower cnicin content (Table 1). Except for ensilaging, any treatment to remove cnicin would be expensive and probably unnecessary since animals have been observed eating immature plants, knapweed silage, and hay.

Our data indicate there is certainly no nutritional reason to restrict animals' consumption of spotted knapweed prior to flowering. Grazing should be encouraged, because it not only reduces forage loss, but can simultaneously decrease knapweed's size and seed production (authors' personal observations). Cox (1983) has reported near elimination of knapweed seed production on pastures once densely covered with knapweed, and the associated grasses have not been overgrazed in the process. This was achieved by allowing the sheep to selectively graze the knapweed in the spring and early summer, then removing them before they heavily grazed the grasses. A second grazing period was required in August to remove the knapweed regrowth (Cox, personal communication). We examined Cox's pastures in September, after a summer of sheep grazing, and found small plants with only a few flowers being produced. The impact of grazing on spotted knapweed needs to be quantified with controlled experiments.

Observations indicate that livestock will eat knapweed silage and hay during winter. In a preliminary experiment the silage prepared in this study was fed to 2 cows in December 1984. Initially they were offered a choice of knapweed silage, and hay with some silage mixed in. By the fourth day both animals were freely eating the silage. In another preliminary trial, a farm flock of Suffolk ewes ate the silage, in place of hay, when offered the first day. At a later date they also ate, without hesitation, the unused portions of the knapweed hay sampled for analysis (Table 3). Local individuals have provided additional observations of knapweed being used as forage. A dairyman reported that his cows like fresh chopped knapweed prior to bloom, and grass/knapweed silage caused no changes in milk production. Dried knapweed has been fed to goats in large quantities during winter without ill effects (Gisselbeck, personal communication). There were also reports that the knapweed hay we analyzed was being fed to cattle. Although further research is essential to measure animal performance, these observations do indicate that most livestock will eat knapweed silage and hay during the winter.

Cutting knapweed prior to flowering should produce a nutritionally acceptable silage or hay and there will be no seeds. Hay containing knapweed could be certified as seed free if cut prior to flowering, but to avoid accidental spread it should be used on site, or confined within infested areas. Harvesting knapweed can also impact its seed production. Watson and Renney (1974) found that a single mowing at bud, or flowering, stages greatly reduced the number of seed-producing plants, and decreased the viability of the seeds that formed.

We want to emphasize that being able to utilize spotted knapweed as forage or feed for livestock does not make the plant desirable; it is still noxious, and should be treated as such. Grazing or harvesting knapweed for forage may provide an economically acceptable method of managing the plants because it can reduce plant size and decrease seed production. It can also be implemented immediately with minimal costs to most land owners. Utilization is not a solution, but an alternative that may be used by some individuals, where feasible, until economically acceptable controls can be developed.

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