J. Range Manage.
46:227-231, May 1993

Nutrient composition of whitetop

MICHAEL L. MCINNIS, LARRY L. LARSON, AND RICHARD F. MILLER

McInnis and Larson are associate professors, Department of Rangeland Resources, Oregon State University, and are stationed at OSU-EOSC Agriculture Program, Eastern Oregon State College, La Grande, 97850; Miller is professor, Department of Rangeland Resources, Oregon State University, and is stationed at Eastern Oregon Agr. Res. Center, HC 71, 4.51 Hwy. 205, Burns 97220.

Abstract

Whitetop or heart-podded hoary cress (*Cardaria draba* (L.)Desv.) is an Eurasian native of the Cruciferae actively invading rangelands throughout western North America. The plant is reported to be unpalatable to livestock and contain potentially toxic glucosinolates. Practical experience indicates sheep consume whitetop during its early growth stages and cattle ingest large quantities of seedheads. Chemical analysis of whole plants from rosette to hard seed, respectively, indicated the following trends: crude protein (28.8 to 7.9%), neutral detergent fiber (13.1 to 52.8%), acid detergent fiber (12.0 to 41.8%), cellulose (9.9 to 32.1%), lignin (1.9 to 9.4%), ether extract (1.6 to 2.4%), in vitro organic matter digestibility (77.3 to 49.1%), digestible energy (2.9 to 1.8 Mcal/kg), and total glucosinolates (28.4 to 84.0 μmol/g). Leaves were higher than stems in crude protein, ether extract, in vitro organic matter digestibility, and digestible energy. Analysis of 11 micro- and macroelements revealed sulfur (S) levels ranged from 0.73 to 2.69% and were therefore higher than the reported maximum tolerable level (0.4%). High S levels likely reflected the S moiety of glucosinolates and their hydrolysis products. Whitetop has some forage value, but until further research establishes the toxicity of this species to sheep and cattle, prudence suggests managers use caution when allowing animals to graze whitetop-infested rangelands by providing supplemental iodine, utilizing mature and nonlactating animals, and reducing opportunities for animals to consume the plant.

Key Words: heart-podded hoary cress, hoary cress, glucosinolates, sheep diets, cattle diets, forage quality, weed control

Whitetop or heart-podded hoary cress (*Cardaria draba* (L.)Desv.) is an Eurasian native of the Cruciferae found throughout western North America. The plant was probably introduced by settlers from Europe in the 1800s and was first collected in the United States at Long Island, N.Y., in 1862 and in Canada at Barrie, Ont., in 1878 (Mulligan and Frankton 1962). By the early 1900s, whitetop was recognized as a noxious weed of agronomic croplands in many areas (Mulligan and Findlay 1974). Land managers are increasingly concerned about the spread of this weed into rangeland ecosystems. Indeed, whitetop possesses several characteristics that make it troublesome. Plants in open ground reach full size about 3 weeks after spring germination, at which time they begin to develop lateral roots (Scurfield 1962). A single plant growing in the absence of competition can spread over an area of 3.7 m in diameter and produce 455 shoots the first year of establishment (Mulligan and Findlay 1974). Seeds mature in late July to early August with a single plant producing 1,200 to 4,800 seeds, of which 84% are viable (Selleck 1965). These characteristics make whitetop an effective competitor with desirable forage, and Larson et al. (1989) estimated a 5% reduction in grass biomass for every 100 kg/ha increase in whitetop.

Whitetop is reported to be mildly toxic (Kingsbury 1964) and generally unpalatable to livestock. Practical experience indicates domestic sheep *(Ovis aries)* consume whitetop during its early growth stages and cattle relish the seedheads during fall. McInnis et al. (1990) demonstrated defoliation of whitetop during its early growth stages could reduce reproductive effort of this weed, and speculated properly timed grazing combined with subsequent herbicide application could be a practical control measure. The purpose of this study was to determine the chemical composition of whitetop relative to animal nutrition.

Research was funded in part by Western Regional IPM Program Grant 86-CSRS-2-2952. The authors gratefully acknowledge the assistance of R.L. Auld and J.B. Davis of the University of Idaho for providing glucosinolate analysis.
Published as Oregon Agr. Exp. Sta. Tech. Pap. 9722.
Manuscript accepted 19 Sept. 1992.

Materials and Methods

Study Area

In 1988 plants were collected from 8 sites near Keating, in Baker County, Ore. Elevations ranged from 900–1,200 m. Annual precipitation was 245 mm, which was near the 10-year average. Mean annual temperature was 9.6° C, with monthly extremes of -2.5° C (January) and 22.5° C (July). The area lies within the shrub-steppe region of Franklin and Dyrness (1973). Native vegetation is dominated by Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis* Beetle), bearded bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), and Idaho fescue (*Festuca idahoensis* Elmer). Disturbed areas are composed principally of cheatgrass brome (*Bromus tectorum* L.) and other annuals, or crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.). Soils of the area are Argixerolls with silt loam surface horizons and clay loam subsoils (Franklin and Dyrness 1973).

Plant Collections

Chemical analyses were conducted on whole plants, leaves, stems, and seeds. Plants were collected from each site during each of 5 phenological stages: rosette (12 April), bolting (24 April), early bloom (12 May), full bloom (10 June), and hard seed (7 July). About 350 g (dry weight) of material was collected at each site by clipping random plants at ground level. Samples were rinsed with distilled water to remove soil and dried at 40° C. Upon drying, samples were ground through a 40-mesh screen and stored in plastic bags for chemical analysis. Samples for glucosinolate analysis were placed on dry ice at collection, stored by freezing, and freeze-dried for analysis (Bradshaw et al. 1983).

Nutrient Analyses

Chemical analyses were conducted on a dry matter basis and included crude protein (AOAC 1984); neutral detergent fiber (Goering and Van Soest 1970); acid detergent fiber, lignin, and cellulose (Van Soest and Wine 1968); ether extract (AOAC 1984); and in vitro organic matter digestibility (Tilley and Terry 1963 as modified by Vavra et al. 1973). Digestible energy was estimated using the equation developed by Rittenhouse et al. (1971): kcal =

Table 1. Mean nutrient composition of whole whitetop plants collected at 5 dates from 8 sites in eastern Oregon, 1988.

Phenology (date)	Dry matter	Crude protein	Neutral detergent fiber	Acid detergent fiber	Cellulose	Lignin	Ether extract	In vitro organic matter digestibility	Estimated digestible energy
	(% dry weight)								(Mcal/kg)[1]
Rosette	22.6a[2]	28.8a	13.1a	12.0a	9.9a	1.9a	1.6a	77.3a	2.93a
(Apr. 12)	(0.8)[3]	(0.9)	(0.3)	(0.4)	(0.3)	(0.1)	(0.1)	(0.4)	(0.02)
Bolting	22.6a	29.5a	16.0a	13.4a	11.2a	2.3a	1.5a	74.7a	2.83a
(Apr. 24)	(0.5)	(0.9)	(0.8)	(0.4)	(0.3)	(0.1)	(0.1)	(0.6)	(0.03)
Early bloom	27.6b	20.3b	23.9b	21.6b	17.0b	4.4b	1.9bc	69.8b	2.61b
(May 12)	(1.5)	(0.8)	(1.1)	(0.9)	(0.9)	(0.1)	(0.1)	(0.9)	(0.04)
Full bloom	33.4c	11.3c	34.9c	28.8c	22.0c	5.9c	2.2cd	64.9c	2.44c
(June 10)	(0.7)	(0.4)	(1.3)	(1.1)	(0.9)	(0.2)	(0.1)	(1.5)	(0.04)
Hard seed	95.9d	7.9d	52.8d	41.8d	32.1d	9.4d	2.4d	49.1d	1.83d
(July 7)	(0.2)	(0.3)	(1.2)	(0.8)	(0.8)	(0.2)	(0.1)	(1.1)	(0.04)

[1]DE = 0.039 (organic matter digestibility) − 0.10 (Rittenhouse et al. 1971).
[2]Means in columns followed by different letters are significantly different ($p<0.01$).
[3]Standard error; n = 8.

DE/kg dry matter = 0.039 (organic matter digestibility) − 0.10. Mineral composition of plant tissues was determined using procedures established by AOAC (1984). Glucosinolates were determined for whole plants and seeds using techniques of Daun and McGregor (1983).

Data Analysis

Chemical constituents were compared among phenological stages using one-way analysis of variance. Differences among means were established ($p<0.01$) with Duncan's multiple range test (Steel and Torrie 1960). Chemical composition of stems. vs. leaves was determined using the *t*-test for unpaired observations.

Results and Discussion

Nutrient levels of whole whitetop plants from rosette through full bloom (Table 1) appeared adequate to meet the requirements of most classes of livestock (Church and Pond 1988) and were more favorable than some native forage species, especially during April (Hickman 1975, McInnis and Vavra 1987). Whitetop accumulates large amounts of nitrogen, as evidenced by the high levels of crude protein (N × 6.25). Whitetop also contained favorable levels of digestible energy. Prior to flowering, whitetop would provide the maintenance requirements for protein and energy of a 60 kg ewe (NRC 1985). As the season progressed, dry matter and components of fiber increased, causing decreases in crude protein, in vitro organic matter digestibility, and digestible energy. Ether extract was least affected and reached its highest level in July, probably because of high concentration in seedheads (Table 2). Compared to stems, leaves were higher in crude protein, ether extract, in vitro organic matter digestibility, and digestible energy (Table 2). Stems were higher in fiber, cellulose, and lignin.

Mineral composition of whole whitetop plants (Table 3) appeared adequate to meet the requirements of cattle and sheep (Church and Pond 1988). Several minerals (K, Ca, Mg, Mn, Fe, and Se) were present in amounts greater than required, but were lower than maximum tolerable levels (NRC 1984, 1985). Sulfur content exceeded the maximum tolerable level of 0.40% (Church and Pond 1988) and likely reflected the S moiety of glucosinolates and their potentially toxic hydrolysis products as discussed below. Soils from which plants were collected did not contain unusual sulfate S levels, as mean soil concentrations collected mid-summer at 0-200 and 200-400 mm of depth were 2.95 and 2.51 ppm, respectively.

Compared to stems, leaves contained higher levels of S, Zn, Mn, and Cu, but less K (Table 4). There were no differences between

Table 2. Mean nutrient composition of whitetop plant parts collected in eastern Oregon, 1988.

Phenology (date) Plant part	Crude protein	Neutral detergent fiber	Acid detergent fiber	Cellulose	Lignin	Ether extract	In vitro organic matter digestibility	Estimated digestible energy
	(% dry weight)							(Mcal/kg)[1]
Early bloom (May 12)								
Stems	9.6	51.4	42.9	35.8	7.1	1.0	57.7	2.15
	(0.9)[2]	(2.6)	(1.3)	(1.1)	(0.2)	(0.1)	(2.4)	(0.09)
Leaves	21.2	17.1	15.7	11.9	3.5	2.1	72.3	2.72
	(1.5)	(0.1)	(0.1)	(0.0)	(0.2)	(0.0)	(0.4)	(0.02)
Significance[3]	*	**	**	**	**	**	*	*
Full bloom (June 10)								
Stems	5.9	55.2	49.3	39.2	10.0	1.3	46.6	1.72
	(0.0)	(1.9)	(1.9)	(0.9)	(0.9)	(0.0)	(3.9)	(0.15)
Leaves	14.0	24.2	20.2	15.3	4.6	2.7	69.2	2.60
	(1.0)	(0.8)	(0.3)	(0.5)	(0.7)	(0.2)	(1.4)	(0.06)
Significance	*	**	**	**	*	*	*	*
Hard seed (July 7)								
Seedheads	16.4	55.0	36.9	26.3	10.6	5.9	44.6	1.64
	(1.0)	(2.2)	(1.9)	(1.7)	(0.2)	(0.6)	(1.5)	(0.25)

[1]DE = 0.039 (organic matter digestibility) − 0.10 (Rittenhouse et al. 1971).
[2]Standard error; n = 8.
[3]* = $p<0.05$, ** = <0.01.

Table 3. Mineral composition of whole whitetop plants collected at 5 dates from 8 sites in eastern Oregon, 1988.

Phenology (date)	S	P	K	Ca	Mg	Zn	Mn	Cu	Fe	Na	Se
	% dry weight					Ppm					
Rosette	2.69a[1]	0.51ab	2.87a	1.12	0.44a	46a	90	6.9a	358ab	1145	0.40
(Apr. 12)	(0.19)[2]	(0.07)	(0.11)	(0.07)	(0.01)	(6)	(9)	(0.2)	(68)	(514)	(0.11)
Bolting	2.52a	0.53a	2.81ab	0.96	0.37ab	48a	63	6.3ab	110b	620	0.65
(Apr. 24)	(0.12)	(0.07)	(0.10)	(0.09)	(0.02)	(5)	(4)	(0.3)	(6)	(94)	(0.28)
Early bloom	1.44b	0.42b	2.55ab	0.95	0.32ab	33ab	61	5.9ab	319ab	683	0.84
(May 12)	(0.10)	(0.06)	(0.10)	(0.05)	(0.02)	(3)	(9)	(0.2)	(76)	(198)	(0.49)
Full bloom	0.99bc	0.29c	2.15bc	1.21	0.40ab	19b	66	5.3b	396ab	2600	1.27
(June 10)	(0.08)	(0.03)	(0.34)	(0.14)	(0.04)	(2)	(12)	(0.5)	(101)	(755)	(0.59)
Hard see	0.73c	0.21c	1.72c	1.09	0.31b	18b	65	5.1b	429a	1414	0.85
(July 7)	(0.06)	(0.04)	(0.12)	(0.14)	(0.02)	(3)	(10)	(0.5)	(91)	(514)	(0.42)

[1]Means in columns followed by different letters are significantly different ($p<0.01$).
[2]Standard error; n = 8.

leaves and stems in amounts of P, Ca, Fe, Na, and Se. Seedheads grazed in July (Table 4) contained minerals in amounts adequate to meet requirements of cattle (Church and Pond 1988). Concentrations of P, K, Mg, Fe, and SE were above required amounts, but below maximum tolerable levels (NRC 1985). The mean level of sulfur contained in seedheads exceeded the maximum tolerable level for cattle (0.40; Church and Pond 1988), probably as a result of high levels of glucosinolates contained in seeds (Table 5).

Fleming et al. (1931) briefly reported whitetop "contains an irritant principle and may cause trouble under conditions of forage shortage". It is now known that 11 families of dicotyledons including the Cruciferae contain glucosinolates (mustard-oil glucosides) that yield glucose, acid sulfate ion, and one or more potentially toxic organic aglucon products upon hydrolysis by an enzyme (thioglucosidase) found in the plant and released when plant material is crushed (Tookey et al. 1980, Chew 1988). Some 90 glucosinolates are known structurally, and more than 60 are present in the Cruciferae; all are sulfur-containing compounds, and most are derived from the amino acid methionine (Al-Shehbaz and Al-Shammary 1987).

Potentially toxic hydrolysis products of glucosinolates at neutral pH include goitrin, thiocyanates, and isothiocyanates (Tookey et al. 1980, Bell 1984, Cheeke and Shull 1985). The former 2 can inhibit thyroid function and may cause thyroid enlargement and growth depression. Isothiocyanates are irritating vesicants that probably would not be consumed in amounts large enough to cause malfunction (Cheeke and Shull 1985); but if consumed as the glucosinolate precursor, with the isothiocyanate released in the gut, they may act as antithyroid agents, especially if the diet contained iodine below the optimal requirement (Tookey et al. 1980). Under some hydrolysis conditions, such as low pH, nitriles are produced (Bell 1984) that can result in poor growth and liver and kidney lesions (Tookey et al. 1980).

Gustine and Jung (1985) noted the difficulty of predicting toxicity of a particular forage on the basis of total glucosinolate content because variations in hydrolytic conditions affect which product is formed, and because specific glucosinolate content and distribution varies among species. Data elaborating the nutritional toxicology of whitetop to sheep and cattle are not available in the literature. However, our data provide clues to the potential of animals being poisoned by this plant. Total glucosinolate content of whole whitetop plants during the rosette and early bloom stages of development (Table 5) approximated that of low-glucosinolate cultivars of rape (*Brassica campestris* L. and *B. napus* L.). The cultivars 'Candle', 'Regent', and 'Erglu' contain 27.7, 25.8, and 15.2 μmol/g, respectively, of total glucosinolates (Bell 1984). The

Table 4. Mineral composition of whitetop plant parts collected from eastern Oregon, 1988.

Phenology (date) Plant part	S	P	K	Ca	Mg	Zn	Mn	Cu	Fe	Na	Se
	% dry weight					Ppm					
Early bloom (May 12)											
Stems	1.10	0.40	2.68	0.58	0.24	23	25	3.8	81	795	0.44
	(0.15)[1]	(0.04)	(0.03)	(0.05)	(0.01)	(3)	(3)	(0.2)	(1)	(225)	(0.22)
Leaves	1.98	0.38	2.43	0.94	0.31	38	68	4.7	762	1465	1.10
	(0.08)	(0.09)	(0.04)	(0.19)	(0.03)	(3)	(3)	(0.3)	(548)	(635)	(0.64)
Significance[2]	*	ns	*	ns	ns	+	**	+	ns	ns	ns
Full bloom (June 10)											
Stems	0.77	0.25	2.14	0.78	0.21	7	37	2.0	139	2350	0.53
	(0.02)	(0.15)	(0.13)	(0.05)	(0.03)	(5)	(16)	(0.0)	(55)	(450)	(0.35)
Leaves	1.67	0.25	1.66	1.58	0.42	17	106	3.1	464	2650	1.26
	(0.09)	(0.06)	(0.00)	(0.34)	(0.00)	(4)	(50)	(0.2)	(175)	(50)	(0.89)
Significance	**	ns	+	ns	*	+	+	*	ns	ns	ns
Hard seed (July)											
Seedheads	0.87	0.51	1.25	0.58	0.31	29	38	6.0	179	422	0.52
	(0.06)	(0.04)	(0.07)	(0.03)	(0.01)	(3)	(6)	(0.4)	(29)	(102)	(0.27)

[1]Standard error; n = 8.
[2]+ = $p<0.1$, * = $p<0.05$, ** = $p<0.01$, ns = nonsignificant.

Table 5. Mean glucosinolate (GS) composition of whitetop collected at 3 dates from 8 sites in eastern Oregon, 1988.

Sample description	n	Glucosinolate			
		4-Methylthio-butyl-GS (Glucoerucin)	p-Hydroxy-benzyl-GS (Sinalbin)	4-Methylsulfinyl-butyl-GS (Glucoraphanin)	Total
		(μmol/g)[1]			
Whole plants, Apr. 14	8	2.1 (0.4)[2]	21.4 (4.3)	2.9 (0.3)	28.4 (3.3)
Whole plants, May 16 (early bloom)	8	2.0 (1.3)	11.6 (0.8)	2.5 (0.3)	15.9 (1.6)
Significance[3]		ns	*	ns	**
Seeds, September 1	1	28.3	55.2	0.5	84.0

[1]Nomenclature follows Tookey et al. (1980); all samples contained a trace (<1.0 μmol/g) of 5-Methylthiopentyl-GS.
[2]Standard error; n = 8.
[3]ns = nonsignificant (p>0.1), * = p<0.05, ** = p<0.01.

development of such low-glucosinolate varieties has made it possible to safely increase the proportion of rapeseed meal fed to livestock (Cheeke and Shull 1985). Total glucosinolate content of whitetop seed (Table 5) was below levels reported for high-glucosinolate cultivars of rape. The cultivars 'Torch', 'Midas', and 'Diamant' contain 93.1, 153.8, and 156.1 μmol/g of total glucosinolate, respectively (Bell 1984). Fisher and Ingalls (1986) reported that a diet containing 25% low-glucosinolate rapeseed meal could be fed to beef and dairy cattle with no adverse effects on performance.

Toxicity of plants containing whitetop is further dependent upon the content of specific glucosinolates and the aglucon products they produce. Whitetop collected from eastern Oregon contained 4 glucosinolates (Table 5). Few studies have examined the glucosinolate content of whitetop, but plants collected in Iraq contained large amounts of 4-methylthiobutyl-GS (glucoerucin), p-hydroxybenzyl-GS (sinalbin), and 4-methylsulfinylbutyl-GS (glucoraphanin) (Al-Shebaz and Al-Shammary 1984). Sinalbin was the most abundant glucosinolate found in eastern Oregon whitetop during the rosette and early bloom stages of growth. Sinalbin and glucoerucin were the primary glucosinolates found in seeds. While glucosinolates occur throughout a plant (roots, stems, leaves, and seeds) (Tookey et al. 1980), we sampled only above-ground tissues. Sinalbin concentration in these tissues declined from rosette to early bloom and was greatest in seeds. At pH 5-7, sinalbin is thought to form unstable isothiocyanates and finally degrade to thiocyanate ion (Tookey et al. 1980, Chew 1988). Toxic symptoms of the former include severe gastro-enteritis, salivation, diarrhea, and irritation of the mouth (Cheeke and Shull 1985). These are likely the symptoms observed by Fleming et al. (1931) when they described the "irritating principle" of whitetop consumed, probably, by animals lacking other forages. Thiocyanate ion acts to inhibits iodine uptake by the thyroid (Tookey et al. 1980). The effect is most pronounced when dietary iodine is low and can be overcome by increasing the iodine level of the diet (Cheeke and Shull 1985). Thiocyanate ion lowers iodine content of milk of lactating animals and can cause goiter in nursing young (Tookey et al. 1980). Further, placental transfer of glucosinolates can occur, increasing the likelihood of goiter and altered serum thyroid hormones in young animals (Cheeke and Shull 1985). At pH 3-4, sinalbin may produce nitriles as the major aglucon products (Tookey et al. 1980). Aglucon products derived from glucoerucin also vary depending on conditions of hydrolysis, and may include isothiocyanates, thiocyanates, and nitriles (Tookey et al. 1980).

Whitetop has some forage value, but until future research establishes the nutritional toxicology of whitetop to ruminants, prudence suggests livestock managers use caution when allowing animals to graze whitetop-infested rangelands. Glucosinolate levels are relatively low during the early growth stages of the plant (rosette to early bloom) when anecdotal observations indicate it is most palatable to sheep. Given the relatively high digestibility of whitetop during spring months (Tables 1, 3) and the knowledge that certain rumen microorganisms produce thioglucosidase (Cheeke and Shull 1985), animals consuming large quantities of whitetop may be exposed to isothiocyanates and thiocyanates. Animals consuming whitetop seeds may also be at risk. In the Pacific Northwest, cattle apparently find the seedheads most palatable during the fall when other forages are less available and concentrations of glucosinolates in whitetop are greatest. Given the moderate digestibility of seedheads (Table 4), and the likelihood that small, hard-coated seeds are passed through the rumen mostly intact (Blackshaw and Rode 1991), conditions may favor the formation of nitriles if hydrolysis occurs in the abomassum at low pH. The potential of animal poisoning may be lessened by providing supplemental iodine; utilizing mature, nonlactating animals; and reducing opportunities for animals to consume the plant, including preventing its invasion into new areas and controlling whitetop where it exists.

Literature Cited

Al-Shehbaz, I.A., and K.I. Al-Shammary. 1987. Distribution and chemotaxonomic significance of glucosinolates in certain Middle-Eastern Cruciferae. Biochem. Syst. Ecol. 15:559–569.

AOAC. 1984. Official methods of analysis (14th ed.). Assoc. Off. Anal. Chem., Washington, DC.

Bell, J.M. 1984. Nutrients and toxicants in rapeseed meal. A review. J. Anim. Sci. 58:996–1010.

Blackshaw, R.E., and L.M. Rode. 1991. Effect of ensiling and rumen digestion by cattle on weed seed viability. Weed. Sci. 39:104–108.

Bradshaw, J.E., R.K. Heaney, G.R. Fenwick, and I.H. McNaughton. 1983. The glucosinolate content of leaf and stem of fodder kale, rape and radicole. J. Sci. Food Agr. 34:571–575.

Cheeke, P.R., and L.R. Shull. 1985. Natural toxicants in feeds and poisonous plants. AVI Publ. Co., Westport, Conn.

Chew, F.S. 1988. Biological effects of glucosinolates, p. 155–181. *In:* H.G. Cutler (ed.), Amer. Chem. Soc. Symp. Ser. 380.

Church, D.C., and W.G. Pond. 1988. Basic animal nutrition and feeding. John Wiley and Sons, N.Y.

Daun, J.K., and D.I. McGregor. 1983. Glucosinolate analysis of rapeseed (Canola). Methods Can. Grain Comm. Grain Res. Lab. Agr. Canada, Winnipeg, Manitoba.

Fisher, L.J., and J.R. Ingalls. 1986. Canola meal for beef and dairy cattle. Canola Counc. Pub. 59. Winnipeg, Manitoba.

Flemming, C.E., M.R. Miller, L.R. Vawter, and A. Young. 1931. Poisonous range plants. Nevada Agr. Exp. Sta. Annu. Rep. 130:12.

Franklin, J.R., and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Serv. Gen. Tech. Rep. PNW-8.

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analysis. Agr. Handb. 379, USDA. U.S. Gov. Print. Off., Washington, D.C.

Gustine, D.L., and G.A. Jung. 1985. Influence of some management parameters on glucosinolate levels in *Brassica* forage. Agron. J. 77:593–597.

Hickman, O.E. 1975. Seasonal trends in the nutritive content of important range forage species near Silver Lake, Oregon. USDA Forest Serv. Res. Pap. PNW-187.

Kingsbury, J.M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, Englewood Cliffs, N.J.

Larson, L.L., M.L. McInnis, R.F. Miller, and J.A. Tanaka. 1989. Forage reduction and seedling emergence by whitetop (Cardaria draba (L.)Desv.). NW Sci. 63:67.

McInnis, M.L., L. Larson, and R.F. Miller. 1990. First-year defoliation effects on whitetop. NW Sci. 64:107.

McInnis, M.L., and M. Vavra. 1987. Dietary relationships among feral horses, cattle, and pronghorn in southeastern Oregon. J. Range Manage. 40:60–66.

Mulligan, G.A., and J.N. Findlay. 1974. The biology of Canadian weeds. 3. *Cardaria draba, C. chalepensis,* and *C. pubescens.* Can. J. Plant Sci. 54:149–160.

Mulligan, G.A., and C. Frankton. 1962. Taxonomy of the genus Cardaria with particular reference to the species introduced into North America. Can. J. Bot. 40:1411–1425.

NRC. 1984. Nutrient requirements of domestic animals. No. 4. Nutrient requirements of beef cattle. Nat. Acad. Sci., Nat. Res. Counc., Washington, D.C.

NRC. 1985. Nutrient requirements of domestic animals. Nutrient requirements of sheep. Nat. Acad. Sci., Nat. Res. Counc., Washington, D.C.

Rittenhouse, L.R., C.L. Streeter, and D.C. Clanton. 1971. Estimating digestible energy from digestible dry and organic matter in diets of grazing cattle. J. Range Manage. 24:73–75.

Scurfield, G. 1962. *Cardaria draba* (L.) Desv. (*Lepidium draba* L.) J. Ecology 50:489–499.

Selleck, G.W. 1965. An ecological study of lens- and globe-podded hoary cresses in Saskatchewan. Weeds 13:1–5.

Steel, R.G.D., and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., N.Y.

Tilley, J.M., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104–111.

Tookey, H.L., C.H. VanEtten, and M.E. Daxenbichler. 1980. Glucosinolates, p. 103–142. *In:* I.E. Liener (ed.), Toxic constituents of plant foodstuffs, Academic Press, N.Y.

Van Soest, P.J., and R.H. Wine. 1968. Determination of lignin and cellulose in acid-detergent fiber with permanganate. J. Assoc. Official Agr. Chem. 51:780-787.

Vavra, M., R.W. Rice, and R.E. Bement. 1973. Chemical composition of the diet, intake and gain of yearling cattle on different grazing intensities. J. Anim. Sci. 36:411–414.

Associate Editor Nominations
Journal of Range Management

Replacements are needed for Associate Editors of the *Journal of Range Management* retiring from the Editorial Board in February, 1994. We are seeking nominees with expertise in the following general areas: animal ecology, economics, grazing management, plant physiology, plant ecology, improvements, and measurement/sampling.

Associate Editors serve for 2 years with an optional 2 additional years with the concurrence of the Editor, *JRM*. To nominate a candidate for this important and demanding position, ascertain that the individual is available and willing to serve and then send a letter of nomination to the Editor describing the nominee's qualifications. Interested individuals may nominate themselves. The candidate will be asked to supply a list of publications and an account of experience in reviewing manuscripts.

Send nominations by **1 Sept. 1993** to: Gary Frasier, Editor, *Journal of Range Management*, 1300 Wheatridge Ct., Loveland, Colorado 80537.