

Evaluation of Rillscale for Herbivore Forage on Bentonite Mine Spoils

Abstract

The forage quality of rillscale (*Atriplex suckleyi*), a native annual species, was evaluated to assess its potential as herbivore forage on bentonite mine spoils. Production estimates were 3432 kg/ha with spoil treatment. Seasonal growth trends and forage quality indicate that rillscale has favorable nutritional qualities for large herbivores. Forage quality was respectable, with dry matter digestibility ranging from 56 percent to 80 percent. Metabolizable energy was 2.51 Mcal/kg and crude protein ranged from 5 to 12 percent. Data for eighteen elements that affect forage quality are presented. These show that rillscale has the capability for making a substantial contribution to the nutrition of large herbivores, although the potential exists for imbalances of iron, magnesium, and zinc.

The major bentonitic deposits in the United States occur in the three-state region of Montana, Wyoming, and South Dakota (Solomon 1973). Most deposits in South Dakota have been depleted and reserves in Wyoming are relatively limited. Montana will experience most intensive development of bentonitic deposits in the next 20 years.

The areal extent of disturbance as a result of bentonite mining is much greater than is generally realized. Disturbance appears to be limited because of the small size (1 to 4 ha) and wide dispersal of pits. A statistical compilation for the state of Montana in 1978 revealed that bentonite mining ranked with coal mining in areal extent of disturbance (Solomon 1973); however bentonite mine spoil, which is sodic, is much more difficult to reclaim (Uresk and Yamamoto 1986, Smith *et al.* 1985, Voorhees *et al.* 1983, Voorhees *et al.* 1987, Sieg *et al.* 1983a).

Industry efforts to comply with reclamation regulations generally include grading, covering with topsoil, and seeding to several plant species conventionally used in reclamation of other types of spoil. There is typically very little vegetative establishment despite these efforts because on most sites salt eventually migrates from spoil to contaminate the soil.

The Forest Research Laboratory in Rapid City has been involved in research on rehabilitation of bentonite mine spoil since the early 1970's. A study to explore and develop the potential of the primary native invader of spoil, rillscale (*Atriplex suckleyi*), was initiated in 1981 after essential failure of several drought- and saline-

tolerant plant species in field trials on abandoned spoil (Uresk and Yamamoto 1986).

Rillscale, a native annual, is a member of a genus valued by range managers, i.e., *Atriplex*. Perennial *Atriplex* species have high forage value (digestibility, protein, palatability, etc.), and some annual species have been cultivated as hay crops. Wildlife and domestic livestock commonly utilize plants of this genus (Shoop *et al.* 1985, Sieg *et al.* 1983b). Herbivore use is the major proposed post-reclamation land use in bentonite-mined regions. Therefore, selection of nutritious and palatable plants is important.

The objectives of this study were to determine productive capabilities, seasonal availability, and forage quality of rillscale. Observations on these parameters are discussed in this paper and incorporated into recommendations for management.

Study Area and Methods

The study area was west of the Black Hills on the Mowry Shale formation in northeastern Wyoming, approximately 2 km northwest of Upton. Sites on the property had been mined at various times during a period of more than 30 years. Elevation at the study area was approximately 1290 m. Average annual precipitation is about 370 mm (National Oceanic and Atmospheric Administration 1983), with 75% received during the growing season from April to September (Thornburg and Fuchs 1978). Vegetation is characteristically big sagebrush (*Artemisia tridentata*) grassland (predominantly *Agropyron smithii* and *Bouteloua gracilis*) interspersed with

stands of ponderosa pine (*Pinus ponderosa*). The area provides forage for livestock and habitat for many species of wildlife, including antelope (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*).

Plots on Raw Spoil

Three sites (replications) were selected on raw spoil in order to characterize biomass and chemical composition of the foliage of rillscale. These sites were selected for level topography and geological uniformity. One 50-m transect was located on each site at random. Aboveground biomass was collected by clipping plants near the spoil surface from ten 0.2-m² quadrats located at 5-m intervals along each transect comprising a total of 30 plots. Quadrats were moved forward 1-m along the transect at each of five sampling dates at equal intervals throughout the growing season so that no quadrat was sampled more than once. Plant tissue samples from each transect were composited for estimation of standing crop and for chemical analyses. Height of the tallest plant within three 10-cm² quadrats in each of ten 1-m² permanent circular plots at equally spaced intervals along each transect was measured at the first three sampling dates.

Plots on Treated Spoil

Culturally treated plots were established on raw spoil in order to assess productive capabilities of rillscale on soils treated with amendments known to have significant positive effects on its growth (Vorhees *et al.* 1987). Gypsum (31 Mg/ha), inorganic chemical nutrient (114 kg/ha N, 23 kg/ha P, 50 kg/ha K), and wood residue (48 mt/ha with 6% added nitrogen) amendments were all applied to each of three tilled plots that were 60 x 150 cm in size. Aboveground biomass was harvested from half of each plot during early July 1983 and from the other half during mid-August for estimation of standing crop. Plant tissue collected from each plot in early July 1983 was used in chemical analyses. Maximum plant height of rillscale in each of five 10-cm² quadrats located at 10-cm intervals along a transect of each plot was measured to the nearest centimeters.

Chemical Analyses

Plant tissue was oven-dried at 55°C, weighed, and ground through a 20-mesh screen. Plant tissue

analyses included total nitrogen by conventional micro-Kjeldahl, in vitro dry matter digestibility (Tilley and Terry 1963), and percentage ash (A.O.A.C. 1985). Crude protein percentage was estimated from Kjeldahl nitrogen ($CP = N\% \times 6.25$).

Elemental concentrations of nitric acid-extractable aluminum, arsenic, barium, boron, calcium, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, sodium, strontium, titanium, and zinc were determined for the plant tissue by using inductively coupled plasma atomic emission spectrometry (ICP-AES) (Fassel and Knisely 1974, Jones 1977, Havlin and Soltanpour 1980, Gestring and Soltanpour 1981).

Statistical Analysis

Mean maximum plant height of rillscale for each treated plot was calculated from the five height measurements, whereas mean maximum plant height for each transect on raw spoil was calculated from values recorded for each of ten quadrats ($n = 3$). Quadrats where no plants were found were excluded from calculations of mean maximum plant height. Standing crop, plant height, and plant tissue compositional parameters of each plot on treated spoil were compared with similar variables for transects on adjacent raw spoil using either a separate or a pooled t-test, as dictated by variance homogeneity ($n = 3$). Box's approximation for evaluating the significance of Bartlett's test was used to evaluate variance homogeneity (Dixon and Massey 1969). Equality of each foliage compositional parameter among treatment dates on raw spoil was tested using classical one-way analysis of variance (F-statistic) when variances were found to be equal using Levene's test. Parameters with unequal variances were tested using statistics that do not assume equality of variances, i.e. Welch and Brown-Forsythe statistics (Brown and Forsythe 1974). Differences were accepted as significant at $p \leq 0.05$.

Results and Discussion

Rillscale is an annual and consequently was expected to have limited seasonal growth and availability due to rapid drying and fragmentation that follow maturity in mid-summer. Figure 1 illustrates the rapid rise and even more rapid

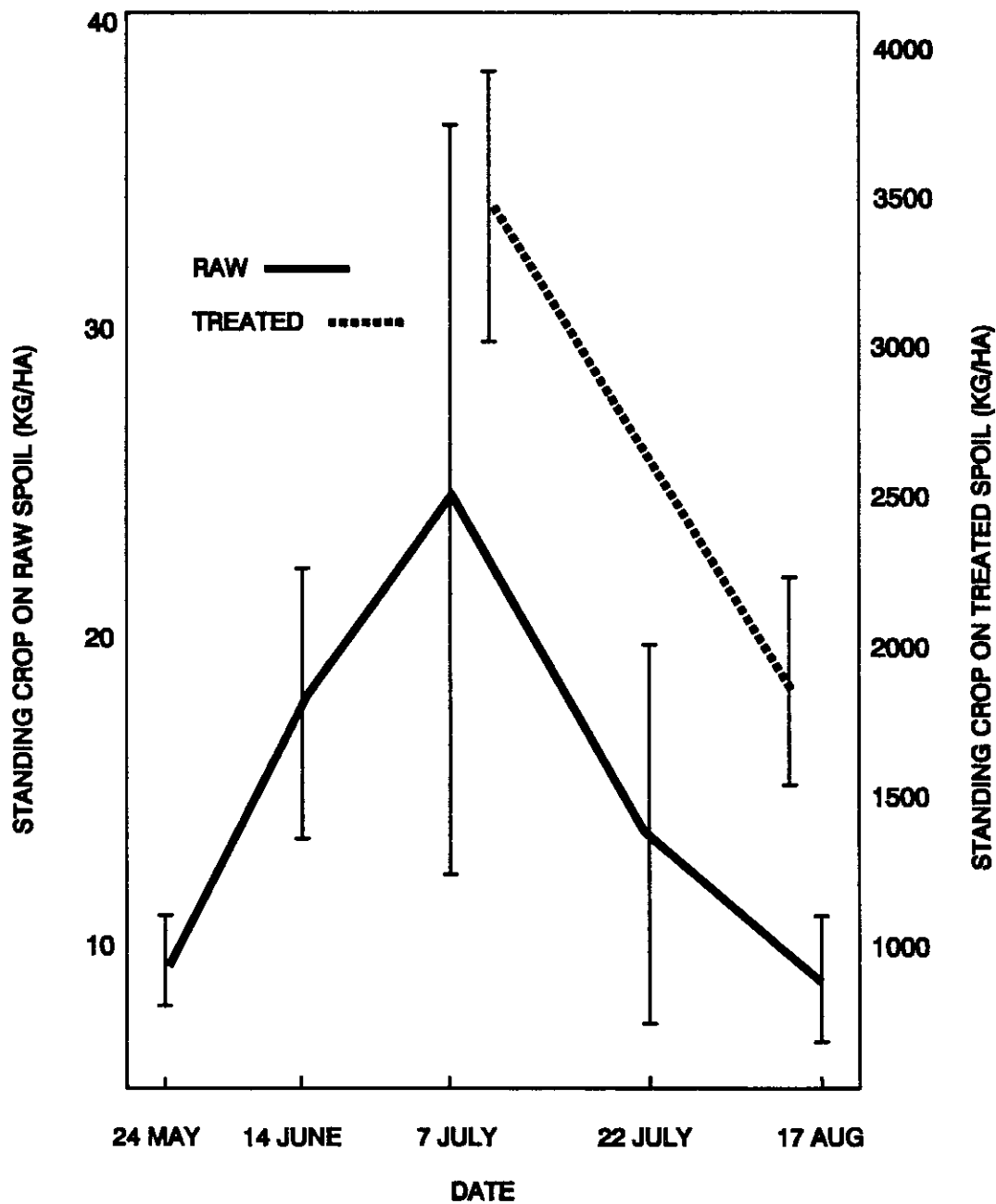


Figure 1. Seasonal growth trends for rillscale grown on raw and treated bentonite spoil with \pm standard error bars.

decline in standing crop of rillscale grown on raw spoil. Peak standing crop (production) on raw spoil (26 kg/ha) was low. Plant heights (Table 1) on raw spoil were near or below the minimum required for substantial utilization by large herbivores, throughout the growing season (Bjugstad

and Whitman 1970).

Rillscale exhibited greatly escalated growth with cultural treatment. Production on treated spoil (3432 kg/ha) was greater than the production of tallgrass prairie under favorable conditions (3300 kg/ha) (Stoddart *et al.* 1975) and

TABLE 1. Mean maximum plant height (cm) of rillscale on raw spoil and on treated spoil at three sampling dates during the 1983 growing season.

Spoil type	Date		
	24 May	14 June	7 July
Raw	1.4a ¹	2.4ab	3.5b
Treated	6.6a*	11.7b*	12.5b*

¹Height values within a spoil type followed by the same letter are not significantly different at $p \leq 0.05$.

*Height values on treated spoil are significantly different from height values on raw spoil on the same date ($p \leq 0.05$).

exceeded critical bite size (Minson 1951) by over 133 percent. Height of plants on treated spoil was adequate for use by cattle on all sampling dates (Table 1). Extrapolation of seasonal growth trends on raw spoil to production on amended spoil (Figure 1) indicated that significant amounts of forage would be available for a minimum of 4 to 6 weeks during favorable years, beginning in early to mid-June and terminating in mid-July if spoil were treated. The period during which adequate forage would be available on treated spoil would actually be longer, because the rate of decline in measured standing crop on treated spoil was significantly lower than on raw spoil.

Rillscale demonstrated acceptable forage quality characteristics (Table 2). Energy and digestibility were high with respect to other common range forages. Digestibility ranged from 56 percent to nearly 80 percent. Metabolizable energy, as estimated from DMD (Rittenhouse *et al.* 1971) for purposes of comparison, was as high as 2.51 Mcal/kg on raw spoil and was increased nearly 20 percent by spoil treatment ($p \leq 0.05$). Alfalfa (*Medicago sativa*) is rated as high as 2.28 Mcal/kg metabolizable energy and 71% dry matter digestibility (National Research Council 1984). The protein content of rillscale (5-12%) was comparable to many range forages.

Rillscale foliage grown on treated spoil had a high salt content as indicated by an average ash content that ranged from 35 percent to 46 percent over the growing season. Sodium content was as high as 7 percent on raw spoil. Such a high sodium content is to be expected as *Atriplex* species generally compensate for a highly saline substrate by accumulating salts. Foliage grown on treated spoil was higher ($p \leq$

0.05) in sodium at 7.8%.

More serious forage quality liabilities of rillscale included potentially toxic levels of iron (as much as 24,900 $\mu\text{g/g}$), manganese (as much as 2555 $\mu\text{g/g}$), and aluminum (as much as 4350 $\mu\text{g/g}$) (Table 2). Iron levels of 100 to 2500 $\mu\text{g/g}$ have been suggested as the lower limit of toxicity for cattle depending on the availability of iron in the particular diet. One thousand $\mu\text{g/g}$ is the maximum tolerable level of aluminum and manganese indicated by the National Research Council for cattle (National Research Council 1984).

High dietary levels of iron as ferrous sulfate have been associated with decreased plasma phosphorus and decreased performance in steers (McDowell 1985). Aluminum toxicity has been implicated as a cause of tetany and phosphorus deficiency (Alfrey 1986).

Manganese is considered the least toxic trace mineral for animals. Decreased feed intake and decreased body weights were associated with a manganese supplemented ration of 2460 ppm and above. Sheep showed similar effects at lower concentrations of dietary manganese (Hurley and Keen 1986).

Mutual antagonism between iron and manganese at the level of absorption may decrease the adverse effects of either. High levels of some elements may have been a result of contamination with spoil material.

The ratio of copper to molybdenum in foliage was adequate on raw spoil at 3.3 to 4.8, but was very much lower ($p \leq 0.05$) on treated spoil at 0.3, which could cause molybdenosis in animals. Molybdenum induced copper deficiencies, expected to occur at copper to molybdenum ratios below 2.0 (Miltmore and Mason 1971), have been documented in this region. Rillscale has been shown to be a molybdenum accumulator (Voorhees, unpublished data), but problems with high molybdenum content of bentonite spoil are probably localized.

Rillscale produced considerable quantities of forage and had valuable forage quality characteristics. Although some potential for elemental toxicities and imbalances exists, these would not develop unless unlikely conditions of intensive, exclusive, and prolonged use of rillscale occurred. Intensive and exclusive use would be unlikely because of the small size (1 to 4 ha) and wide

TABLE 2. Standing crop and chemical composition of the foliage of rillscale grown on raw bentonite mine spoil at five sampling dates during 1983.

Property (units)	Raw Spoil				Treated Spoil	
	Date					
	24 May	14 June	7 July	22 July	17 Aug.	7 July
Standing crop (kg/ha)	7ab ¹	18ab	26b	11ab	4a	3432*
Dry matter digestibility (%)	71b	79b	59a	60a	56a	71
Crude protein (%)	12c	10bc	8abc	5a	6ab	13
Ash (%)	36a	35a	40ab	45b	46b	34
Ca (%)	0.49a	0.47a	0.56ab	0.70b	0.70b	0.48*
Mg (%)	1.28a	1.41a	1.25a	1.21a	1.22a	0.83
P (%)	0.31c	0.27bc	0.11a	0.12a	0.17ab	0.16
Na (%)	6.36bc	7.01c	5.16ab	3.94a	4.80ab	7.76*
K (%)	1.80a	1.59a	1.42a	1.13a	1.11a	1.04
Zn (µg/g)	92ab	85a	104ab	129b	101ab	65
Fe (µg/g)	8345a	5930a	17000b	22000bc	24900c	10350
Mn (µg/g)	479a	371a	1280ab	2555b	1633ab	423
Ni (µg/g)	16a	16a	18a	29a	17a	7*
Cr (µg/g)	5ab	4a	8bc	12d	8c	7
Cu (µg/g)	10ab	7a	13abc	17c	12bc	6*
Mo (µg/g)	2a	2a	3ab	6b	3ab	24
B (µg/g)	39ab	49b	27a	33ab	30ab	43
Al (µg/g)	3120b	1357a	2825ab	4350b	3360b	1370
Ba µg/g)	55a	25a	22a	75a	81a	52
Sr µg/g)	49a	42a	70ab	116b	108b	100*
Ti µg/g)	8ab	6a	5a	12b	7a	10
Cu:Mo	4.75a	3.50a	4.17a	3.31a	4.72a	0.28*

¹Values for a given parameter within a spoil type that are followed by a similar letter are not significantly different at $p \leq 0.05$.

*Values for a given parameter on treated spoil are significantly different from similar parameters of foliage on raw spoil on the same date ($p \leq 0.05$).

dispersal of pits over the region. Animals do not appear to selectively seek rillscale though they have been observed to utilize it as forage. Prolonged use would be unlikely because of the relatively short periods of time during which rillscale is available as forage. Assessment of the composition of the diets of wildlife and livestock that forage on these areas would be prudent and useful to determine palatability and toxic potential. Theoretically other plant species could be planted with rillscale (Uresk and Yamamoto 1986, Welch 1989) to further decrease the possibility of dietary imbalances and toxicities although results of previous field trials utilizing other species indicate practical limitations to this approach.

Conclusions

Rillscale has potential for use in revegetation of spoil and for use as forage. This plant demonstrated a capability for making a substantial contribution to the nutrition of large herbivores, especially when spoil treatments were applied.

However, the potential for toxicities and imbalances of rillscale for herbivores may exist for iron, manganese and aluminum. High concentrations of these elements may reflect spoil contamination of foliage. Foliage samples were not washed in order that they might more truly represent what would be ingested by a foraging herbivore. Native forage on undisturbed areas adjacent to spoil might be a potential hazard as well if this is the case. This possibility deserves investigation because it represents a potential loss in grazing value that perhaps has not been considered. Although the degree of rillscale consumed is unknown, cattle and deer have been observed by the authors to utilize rillscale as forage.

Acknowledgments

Thanks are extended to Joe Trlicia, Department of Range Science, Colorado State University, Ft. Collins, CO for his helpful suggestions throughout the study. American Colloid provided study areas.

Literature Cited

- Alfrey, A. C. 1986. Aluminum. In Morris, E. R. (ed.), Trace elements in human and animal nutrition. 5th edition. Volume 2, Academic Press, New York. Pp. 399-413.
- A.O.A.C. 1985. Official methods of analysis. Association of Official Agri. Chemists. Washington, DC.
- Brown, M. B. and A. B. Forsythe 1974. Robust tests for the equality of variances. J. Amer. Statist. Assoc. 69:364-367.
- Bjugstad, A. J., and W. C. Whitman. 1970. Significance of reduced plant vigor in relation to range condition. J. Range Manage. 23:181-184.
- Dixon, W. J., and F. J. Massey, Jr. 1969. Introduction to statistical analysis. 3rd ed., McGraw-Hill, N.Y.
- Fassel, V. A., and R. N. Knisely. 1974. ICP-Optical emission spectroscopy. Anal. Chem. 46:1110A.
- Gestring, W. D., and P. N. Soltanpour. 1981. Boron analysis in soil extracts and plant tissue by plasma emission spectroscopy. Commun. Soil Sci. Plant Anal. 12:733-742.
- Havlin, J. L., and P. N. Soltanpour. 1980. A nitric acid plant tissue digest method for use with inductively coupled plasma spectrometry. Commun. Soil Sci. Plant Anal. 11:969-980.
- Hurley, L. S., and C. L. Keen 1986. Manganese. In Morris, E. R. (ed.), Trace elements in human and animal nutrition. 5th edition. Volume 1, Academic Press, New York. Pp. 185-224.
- Jones, J. B., Jr. 1977. Elemental analysis of soil extracts and plant tissue ash by plasma emission spectroscopy. Commun. Soil Sci. Plant Anal. 8:349-365.
- McDowell, L. R. 1985. Iron, manganese and zinc. In McDowell, L. R. (ed.), Nutrition of grazing ruminants in warm climates. Academic Press, New York. Pp. 440-443.
- Miltmore, J. E., and J. L. Mason. 1971. Copper to molybdenum ratio and molybdenum and copper concentrations in ruminant feeds. Can. J. Anim. Sci. 51:193-200.
- Minson, D. J. 1981. Characteristics of the nutritionally ideal grazing plant. In: J. L. Wheeler and R. D. Mochrie. (eds.), Forage evaluation: concepts and techniques. Symposium proceedings. October 1980. Armidale, NSW. CSIRO and the Amer. Forage and Grassland Council, Lexington, Ky. Pp. 543-550.
- National Oceanic and Atmospheric Administration. 1983. Wyoming climatological data: annual summary. Environmental Data and Information Center, National Climatic Center, Asheville, N.C. 27 p.
- National Research Council. 1984. Nutrient requirements of domestic animals. No. 4, Beef Cattle. 6th ed. National Academy of Science, Washington, D.C. 90 p.
- 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.
- Shoop, M. C., R. C. Clark, W. W. Laycock, and R. M. Hansen. 1985. Cattle diets on shortgrass ranges with different amounts of fourwing saltbush. J. Range Manage. 38:443-449.
- Sieg, C. H., D. W. Uresk, and R. M. Hansen. 1983a. Plant soil relationships on bentonite mine spoils and sagebrush-grasslands in the northern High Plains. J. Range Manage. 36:289-294.
- _____. 1983b. Seasonal diets of deer mice on bentonite mine spoils and sagebrush grasslands in southeastern Montana. Northw. Sci. 60:81-89.
- Smith, J. A., G. E. Schuman, E. J. DePuit, and T. A. Sedbrook. 1985. Wood residue and fertilizer amendment of bentonite mine spoils: I. Spoil and general vegetation responses. J. Env. Quality 14:575-579.
- Solomon, S. 1973. "Bentonite summary," prepared for the Montana State Legislature and Division of the Montana Department of State Lands. 10 p.
- Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range management. 3rd ed. McGraw-Hill, N. Y.
- Thornburg, A. A., and S. H. Fuchs. 1978. Plant materials and requirements for growth in dry regions. In F. W. Schaller and P. Sutton (eds.), Reclamation of drastically disturbed lands. Symposium proceedings. August 1976. Wooster, Ohio. Amer. Soc. Agron. Inc., Madison, Wis. Pp. 411-423.
- Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.
- Uresk, D. W., and T. Yamamoto. 1986. Growth of forbs, shrubs and trees on bentonite mine spoil under greenhouse conditions. J. Range Manage. 39:113-117.
- Voorhees, M. E., D. W. Uresk, and R. M. Hansen. 1983. *Atriplex suckleyi* (Torry) Rydb.: In Proceedings—symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, Utah (Compilers Arthur R. Tiedemann *et al.*). Gen. Tech. Rep. INT-172. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. Pp. 53-58.
- Voorhees, M. E., M. J. Trlica, and D. W. Uresk. 1987. Growth of rillscale on bentonite mine spoil as influenced by amendments. J. Env. Quality 16:411-416.
- Welch, B. 1989. Nutritive value of shrubs. In McKell, C. M., editor. The Biology and Utilization of Shrubs. Univ. Res. Park, Salt Lake City, UT. Academic Press, Inc., New York. Pp. 405-424.

Received 12 May 1989

Accepted for publication 6 February 1990