NATURAL GROWTH OF ATRIPLEX SUCKLEYI ((Torrey) Rydb.) ON BENTONITE MINE SPOILS IN SOUTHEASTERN MONTANA

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ABSTRACT: Rillscale (Atriplex suckleyi (Torrey)Rydb.) was the most common and productive plant on bentonite mine spoils, comprising between 40 and 94 percent of the total plant canopy cover and standing crop on the mine spoils; yet, it was uncommon on the unmined sagebrush-grass sites. The success of rillscale on the mine spoils was attributed to its adaptation to the climatic and edaphic conditions of the area, an adequate seed source, and the absence (or near absence) of competing vegetation. Soil compaction, high sodium concentrations, and acidic soils limited growth of rillscale on some mine sites.

INTRODUCTION

Rillscale (Atriplex suckleyi (Torrey) Rydb.) is an annual chenopodiaceous plant limited to the Great Plains of North America (McNeill and others 1979). It occurs in Alberta and Saskatchewan, Canada, and in Montana, Wyoming, North Dakota, South Dakota, and Nebraska in the United States (Frankton and Bassett 1970). Also known as scurfless saltbush, and previously named A. dioica (Nutt.) Macbride (Frankton and Bassett 1970), rillscale is limited to alkaline or badland sites (Hitchcock and Cronquist 1973), and is a common plant on bentonite mine spoils in Montana, Wyoming, and South Dakota. This study was designed to sample the plant canopy cover and standing crop of rillscale on bentonite mine spoils and sagebrush-grass rangeland in southeastern Montana, and to identify soil and other enviromental characteristics which limit its establishment.

STUDY AREA

This study was conducted in extreme southeastern Montana, approximately 6 miles (9km) west of the town of Alzada. The study area was on a dense clay-clayey-saline upland range site complex, as defined by Ross and Hunter (1976), at an elevation of approximately 3,300 to 3,600 ft (1000-1100 m). Annual average precipitation is 15 inches (37 cm), most of which falls between May and July (U.S. Department of Transporation, National Oceanic and Atmospheric Administration 1976). In 1979 and 1980, 10 and 14 inches (26 and 35 cm) of precipitation fell, re-spectively. The May to July precipitation for 1979 was 6 inches (15 cm), while only 4 inches (11 cm) fell during this period in 1980. Vegetation consists mainly of big sagebrush (Artemisia tridentata Nutt.) with an understory of western wheatgrass (Agropyron smithii Rydb.), blue grama (Bouteloua gracilis (H.B. K.) Steud.), and buffalograss (Buchloe dactyloides (Nutt.) Engelm.). Vegetation on bentonite mine spoils in the study area is dominated by rillscale (Sieg and others 1983).

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METHODS

Twelve study sites were selected: ten on bentonite mine spoils resulting from mining activites between 1952 and 1978, and two on adjacent, unmined rangeland. The study sites were classified into four types: (1) old mine spoils; (2) reclaimed spoils; (3) semireclaimed spoils; and (4) sagebrush-grass rangelands. Five sites were established on old spoils (predating reclamation laws), which were 12 to 28 years old, steep, and nearly devoid of vegetation. Three sites were established on 5- to 12-year-old reclaimed spoils, which had been recon-toured, spread with topsoil and seeded with a mixture of wheatgrasses (Agropyron spp.) and yellow sweetclover (Melilotus officinalis (L.) Lam.). Two sites were established on semireclaimed spoil piles, which were the result of mining the previous fall. One of the semireclaimed spoils was seeded with wheat-grasses and yellow sweetclover during the fall of the first year of the study. The steep grade of the other pile prevented seeding. Two sites were estab-blished on gently undulating unmined sagebrush-grass rangeland. All sites were accessible to sheep and cattle.

Plant canopy cover and standing crop were sampled on the 12 sites on a regular basis for 2 years. Plant canopy cover was estimated in June, July, and August each year in 150, 1.1-ft^2 (0.1-m^2) quadrats, spaced at 3.3-ft (1-m) intervals, along three permanent 164-ft (50-m) transects on each site (Daubenmire 1959). Canopy cover was visually estimated by seven cover classes: 0 = less than 1 percent cover, 1 = 1 to 5 percent, 2 = 5 to 25 percent, 3 = 25 to 50 percent,

4 = 50 to 75 percent, 5 = 75 to 95 percent, and 6 = 95 to 100 percent cover.

Plant standing crop was estimated by harvesting plants at ground level annually, at peak production (late July), on all sites. At each site, plants were clipped in ten 8-inch X 20-inch (20-cm X 50-cm) quadrats, on each of three permanent transects, were ovendried in the laboratory at 140° F (60° C) for 48 hours, and were weighed.

Twenty soil samples were taken on each site during the second year, to a depth of 4 inches (10 cm), with a 2-inch (5-cm) soil probe mounted on a drill truck. A grid pattern with 49-ft (15-m) spacing was used to distribute the samples throughout the sites. Four composite subsamples were analyzed from each site: two from the first 10 samples, and two from the next 10 samples. Available levels of sodium and pH were analyzed by standard techniques (United States Salinity Laboratory Staff 1954).

Soil compaction was measured with a hand-held penetrometer scaled from 0 to 4.5 ton/ft^2 (0-4.5kg/cm^2). The load required to read 4.5 ton/ft^2 (4.5kg/cm^2) was 17 lb (7.7 kg). Twelve measurements were taken in a grid pattern with 46-ft (14-m) spacing, on each site, every 3 weeks from May to October, during the second year of the study, for a total of 96 measurements per site.

Analysis of variance and Tukey's multiple comparison procedure (Kleinbaum and Kupper 1978) were used to compare plant canopy cover, average aboveground biomass, and soil properties among site types, months, and years. Regression analyses were used to compare peak standing crop and plant canopy cover of rillscale to soil characteristics.

RESULTS

Plant Canopy cover

The plant canopy cover of rillscale ranged from 1 to 8 percent on the mine spoils, and rillscale comprised between 40 and 94 percent of the total cover on these sites (table 1). Yet, rillscale was nearly absent on the sagebrush-grasslands. The cover of rillscale did not differ significantly ($P > 0.1$) from month to month, yet it varied ($P < 0.05$) between years. In 1979, the cover of rillscale was higher ($P < 0.05$) on reclaimed spoils than other sites, and was similar ($P > 0.01$) on semi-reclaimed spoiles, old spoils, and sagebrush-grass rangelands. However, in 1980, canopy cover of this pioneer plant increased ($P < 0.001$) on semireclaimed spoils and decreased ($P < 0.05$) on other spoils. This resulted in similar cover values on the mine spoils, but higher ($P < 0.05$) cover values on these sites than on the sagebrush-grasslands. Plant canopy cover of rillscale on bentonite mine spoils was negatively correlated with penetrometer readings ($r = -0.52$, $P = 0.001$) and sodium concentrations ($r = -0.57$, $P = 0.001$), and positively correlated with pH ($r = 0.26$, $P = 0.1$).

Plant Standing Crop

Plant standing crop of rillscale ranged from less than 3 lb/acre (3 kg/ha) to 169 lb/acre (190 kg/ha), and accounted for 40 to 93 percent of the total standing crop on the mine spoils; whereas rillscale comprised only a small portion (<1 percent) of the standing crop on sagebrush-grasslands (table 2). In 1979, standing crop of rillscale was higher ($P < 0.05$) on reclaimed spoils (averaging 138 lb/acre (155 kg/ha) than on other sites, and did not differ ($P > 0.1$) on old spoils,

Table 1.--Range and average percent plant canopy cover of rillscale and percent of tatal plant cover on bentonite mine spoils and sagebrush-grass reangeland near Alzada, Mont., in 1979 and 1980.

	1979			1980		
	Percent canopy cover		Percent of	Percent canopy cover		Percent of
Site type	Range	$\bar{x}$	total cover	Range	$\bar{x}$	total cover
Old spoils	<1-6	2.6[1]	68	<1-4	1.8[2]	72
Reclaimed spoils	8-9	8.3[2]	60	3-5	3.6[2]	40
Semireclaimed spoils	<1	<1[1]	46	3-7	4.9[2]	94
Sagebrush-grasslands	<1	<1[1]	<1	<1	<1[1]	<1

[1],[2]Means followed by the same letter superscript (within years) were not significantly different ($P > 0.05$).

semireclaimed spoils, and sagebrush-grasslands. However, in 1980, the standing crop of rillscale decreased ($P < 0.05$) on reclaimed and old spoils and increased ($P < 0.01$) on semireclaimed spoils. In 1980, the standing crop of rillscale was higher ($P < 0.1$) on semireclaimed spoils than on other sites, was higher ($P < 0.05$) on reclaimed spoils than on old spoils or sagebrush-grasslands, and was similar ($P > 0.1$) on old spoils and sagebrush-grass sites. Plant standing crop of rillscale on the bentonite mine spoils was negatively correlated with penetrometer readings ($r = -0.29$, $P = 0.07$) and sodium concentration ($r = -0.55$, $P = 0.001$), and positively correlated with pH ($r = 0.46$, $P = 0.003$).

Soils

Soils characteristics were highly variable on the bentonite mine spoils. In general, acidic pH values, high sodium concentrations, and compaction were common. More than 50 percent of the pH readings on old mine spoils were moderately to strongly acidic (table 3). Eight percent of the readings on reclaimed spoils were strongly acidic (pH 4.0 to 4.9), while pH values on semireclaimed spoils and sagebrush-grasslands were all slightly acidic (pH 6.0 to 6.9) to slightly alkaline (pH 7.0 to 7.9).

Sodium concentrations also were highly variable. Average concentrations on old spoils ranged from less than 2,000 ppm (10 percent of the samples) to more than 7,000 ppm (35 percent of the samples) (table 4). Average sodium concentrations on the reclaimed spoils were all less than 4,600 ppm, while 63 percent of the samples from semireclaimed spoils averaged between 4,600 and 6,900 ppm. Eighty-eight percent of the samples from sagebrush-grass rangelands contained sodium levels of less than 2,000 ppm (table 4).

Between 31 and 53 percent of the penerometer readings on bentonite spoils averaged be-tween 4.0 and maxmium reading (4.5 ton/ft^2). Only 7 percent of the readings on the sagebrush-grasslands averaged above 4.0 (table 5). The majority of the penetrometer readings on the sagebrush-grass rangelands averaged less than 2.0, while fewer than one-third of the readings on the bentonite spoils averaged less than 2.0.

DISCUISSION

Bentonite mining activites and resultant spoil piles in southeaster Montana provided environments suitable for the establishment of rillscale. The presence and dominance of rillscale on bentonite mine spoils demonstrated the ability of this plant to rapidly colonize barren sites. The success of rillscale on the mine spoils (as plant cover and standing crop), when compared to seeded species or other native plants, was attributed to its adaptation to the climatic and edaphic conditions of the area, the absence (or near absence) of competitive vegetation, and an adequate seed source. The most inhibiting feature of the sagebrush-grasslands for the growth of rillscale was competition from other plants. The few rillscale plants observed on the sagebrush-grassland communities were limited to barren microsites.

The negative correlations of the cover and production of rillscale with penetrometer readings and sodium concentrations and positive correlation with pH indicate that certain soil (or spoil) characteristics are inhabiting to the growth of rillscale on bentonite mine spoils. With increasing compaction, excessive sodium concentration, and low pH, rillscale is less likely to grow. High compaction lessens the likelihood that plant roots would be able to

Table 2.--Range and average plant standing crop of rillscale, and percent of total standing crop on bentonite mine spoils and sagebrush-grass, rangelands near Alzada, Mont., in 1979 and 1980.

	1979			1980		
	Plant standing crop (lb/acre)		Percent of	Plant standing crop (lb/acre)		Percent of
Site type	Range	$\bar{x}$	total crop	Range	$\bar{x}$	total crop
Old spoils	3-65	29[1]	57	0-55	19[1]	40
Reclaimed spoils	117-169	138[2]	50	54-79	68[2]	51
Semireclaimed spoils	10-21	16[1]	49	101-140	120[3]	93
Sagebrush-grasslands	0-3	2[1]	<1	0-2	1[1]	<1

[1],[2],[3]Means followed by the same letter superscript (within years) were not significantly different ($P > 0.05$).

Table 3.--Classification of soil samples (0-4 inches) taken on bentonite mine spoils and sagebrush-grasslands near Alzada, Mont., according to pH.

Classification	pH	Percent of samples			
		Bentonite mine spoils			Sagebrush-grasslands
		Old	Reclaimed	Semireclaimed	
Strongly acidic	(4.0 - 4.9)	45	8	0	0
Moderately acidic	(5.0 - 5.9)	15	0	0	0
Slightly acidic	(6.0 - 6.9)	25	33	63	25
Slightly alkaline	(7.0 - 7.9)	15	59	37	75

Table 4.--Distribution of soluble and exchangeable sodium concentrations in soil samples (0-4 inches) taken on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont.

Na concentration (ppm)	Percent of samples			
	Bentonite mine spoils			Sagebrush-grasslands
	Old	Reclaimed	Semireclaimed	
0 - 2,000	10	33	0	88
2,000 - 4,600	40	67	37	12
4,700 - 6,900	10	0	63	0
> 7,000	40	0	0	0

Table 5.--Distribution of penetrometer readings taken on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont.

Penetrometer reading (ton/ft^2)	Percent of samples			
	Bentonite mine spoils			Sagebrush-grasslands
	Old	Reclaimed	Semireclaimed	
0 to 0.9	4	5	2	39
1 to 1.9	11	20	19	28
2 to 2.9	13	17	30	18
3 to 3.9	19	20	18	8
4 to 4.5	53	38	31	7

penetrate the substrate. However, halophytic plants such as rillscale generally can become established in high-sodium media. Sodium centrations on some of the mine spoils are apparently towards the upper range of tolerance for this plant. Further, rillscale appears to more highly adapted to neutral or slightly alkaline soils, and is less tolerant of acidity. Low pH values are caused by the formation of sulfuric acid from inherent sulfate ions which neutralizes the alkaline effects of spoil (Bjugstad and others 1981).

The combination of these factors may explain the lower cover (in 1979) and production (in both years) of rillscale on old spoils, compared to reclaimed spoils. High penetro-meter readings, high sodium concentrations, and low pH were very common on old spoils, and comparatively less common on reclaimed spoils. Despite the near absence of com-petition from other plants on the old spoils, rillscale was inhibited by adverse spoil characteristics.

Differences in the plant cover and production of rillscale on semireclaimed spoils are more difficult to explain. The 1979 data were collected the first growing season after the spoils materials were recontoured and spread with topsoil. The low cover and standing crop of rillscale on semireclaimed spoils in 1979 suggest that at least one growing season is required for the accumulation of rillscale seeds to a level where this plant becomes an important component of the plant community. The flourish of rillscale the second year after reclamation may be interpreted as evidence of an adequate seed source, acceptable soil conditions, and very little competition from other plants. Acidic pH readings were not detected on the semi-reclaimed spoils, and these spoils were not as compacted as old spoils. Although most samples registered between 4,700 and 6,900 ppm of soluble and exchangeable sodium, none of the samples registered above 7,000 ppm. (forty percent of the samples on old spoils were above 7,000 ppm.) Plant compitition was unlikely on the semireclaimed spoils, because rillscale accounted for over 90 percent of the cover and production on these sites in 1980.

The decline in the plant canopy cover and standing crop of rillscale on reclaimed and old spoils in 1980, contrasted to the dramatic increase on semireclaimed spoils, indicated that the growing environments on old and reclaimed spoils have characteristics nearing the tolerance limits of rillscale, and that when this plant is stressed by drought, it is less likely to grow. The inhibiting feature for rillscale on reclaimed spoils, as compared to semireclaimed spoils, was likely competition from other plant species and possibly a few microsites of acidic soils. Otherwise, penetrometer readings were comparable on both reclaimed and semireclaimed spoils, and neither site type had sodium concentrations greater than 7,000 ppm. Greater soil compaction, higher sodium concentrations, and more acidic pH were inhibiting features for the growth of rillscale on old bentonite mine spoils when compared to semireclaimed spoils. These factors, coupled with drought in 1980, resulted in lower production of rillscale on the old spoils.

This study demonstrated that rillscale, a native annual forb, is highly adapted to bentonite mine spoil environments in south-eastern Montana. However, the standing crop and plant canopy cover of rillscale are limited by excessive soil compaction, high sodium concentrations, and acidic soils on some sites, particularly in combination with low precipitation. In general, reclaimed spoils provided better growing media for the establishment of rillscale than unreclaimed spoils, in the absence (or near absence) of competitive vegetation.

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