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SOIL-SITE RELATIONSHIPS OF WHITE LOCOWEED ON THE RAFT RIVER MOUNTAINS

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ABSTRACT.—White locoweed (*Oxytropis sericea* Nutt.) is restricted to the top and windswept ridges of the Raft River Mountains. Elevation and soil characteristics have the greatest effect on its occurrence. It is most abundant on the subalpine windswept ridge ecological site (9.2 plants/m^2) above 2,380 m. White locoweed apparently can tolerate the extreme environmental stresses of the shallow, rocky, windswept ridges where it is one of the dominant species. White locoweed also occurs in the deep, subalpine loam site (3.8 plants/m^2) above 2,865 m, but it is a minor component of this plant community. It is apparently less competitive on the deeper soils, and its population fluctuates more. It exhibits an opportunistic survival strategy on the subalpine loam site by having a large reserve of viable seeds in the soil ready to germinate and establish when environmental conditions are favorable, and then declines with competition from more robust species.

White locoweed (*Oxytropis sericea* Nutt.) is one of the most widely distributed locoweeds. It occurs on the plains, prairies, and foothills of the Rocky Mountains and is common from western Montana to the Black Hills of South Dakota, south to Oklahoma and central New Mexico, and occasionally westward to southern Utah, northeastern Nevada, and southern Idaho. It occurs mostly between 900 and 2,100 m altitude, occasionally reaching 3,350 m in the southern Rockies (Barneby 1952).

White locoweed is locally present on the top of the Raft River Mountains in northwestern Utah, where it has caused substantial livestock loss by inducing locoweed poisoning (James et al. 1981) and high mountain brisket disease (James et al. 1983). Historical reports (Gordon Carter, personal communication, 15 October 1983) indicate that white locoweed occurred lower on the sides of the mountains than it does presently. Currently, it is restricted to the flat mountain top. The objectives of this study were to describe the ecological sites and soils where white locoweed occurs and to define the relationship of white locoweed populations to soil characteristics and associated plant communities.

Methods and Materials

An order 3 soil survey was conducted on mountainous rangelands of western Box Elder County in 1984 by the Soil Conservation Service (SCS) and the U.S. Forest Service. Ecological sites (synonymous with range sites in SCS terminology) were delineated and described. White locoweed occurred on four ecological sites near the top of the Raft River Mountains but did not appear on any other mountain ranges in the survey. The four sites differ in respect to elevations and soils. In 1985 a cluster of three paced transects was established in the center of each site where it occurred on the mountain. Twenty 0.1-m^2 plots were located along the transects at 10-step intervals. The number of mature and juvenile white locoweed plants in each plot was counted. Plants with three or fewer pinnately compounded leaflets were considered juvenile. Data were analyzed by analysis of variance (ANOVA) to compare differences among sites. Clusters within sites comprised the error term used in the F test. Where there were significant differences among sites, means were separated by Duncans multiple range test.

Percentage frequency of occurrence of white locoweed and other associated species was calculated to describe the plant communities on each site. Mean values for each cluster represented density or frequency of the species at each location. The mean of all clusters within an ecological site was calculated, and the standard error of the mean (SE) is reported to show the variability among locations within the same ecological site.

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TABLE 1. Soil families and ecological sites on which white locoweed occurs on the Raft River Mountains.

Soil	Symbol	Ecological site	Elevation (m)
Nielsen (loamy-skeletal, mixed, Argic Lithic Cryoborolls)	SAR LSR	Subalpine windswept ridge Mountain windswept ridge (low sage)	2,380–3,050 < 2,380
Bickmore (loamy-skeletal, mixed, Argic Pachic Cryoborolls)	SAL HML	Subalpine loam High mountain loam	2,865–3,050 2,600–3,050

Density, population dynamics, and production of white locoweed had been studied intensively at the Rosevere location since 1981. Seven permanently marked transects on the subalpine loam ecological site and five transects on the subalpine windswept ridge ecological site were read weekly from 1981 to 1986. Frequency of occurrence and the number of mature and juvenile white locoweed were recorded. The mean values averaged over weeks are presented for each year.

Weather records were obtained from the SCS snow survey and the Utah Climatological Bulletin to correlate changes in white locoweed density with weather patterns. Accumulation of winter precipitation as of 1 April was taken from a snow course station 4 km west at an elevation 100 m below the study site. Monthly precipitation during the growing season was obtained from the Snowville reporting station, 48 km east and 1,200 m below the study site. These weather records do not reflect the specific conditions at the study site but do indicate the trend of weather patterns for the region. Simple linear regression was used to compare the change in locoweed density over years and to determine the influence of precipitation on locoweed density.

RESULTS

Description of Ecological Sites

WINDSWEPT RIDGE.—Soils of these sites are of the Nielsen family (loamy-skeletal, mixed Argic Lithic Cryoborolls), 25–50 cm to bedrock (Table 1). Coarse rock fragments comprise 35–65% of the volume. These sites occupy the shallow, rocky ridgetops and convex slopes. An elevational stratum occurs about 2,380 m (7,800 ft) in the plant community. Alpine sagebrush (*Artemisia scopulorum* Gray) is the dominant shrub on the subalpine windswept ridge site above 2,380 m, while low sagebrush (*Artemisia arbuscula* L.) dominates the mountain windswept ridge site below 2,380 m (Table 2). Bluebunch wheatgrass [*Agropyron spicatum* (Pursh) Scribn & Smith] and sandberg bluegrass (*Poa sandbergii* Vasey) are the dominant grasses on both sites. Fleabane daisy (*Erigeron leiomerus* Gray) and phlox (*Phlox hoodii* Rich.) are prevalent on both sites, but white locoweed is the dominant forb on the subalpine site. It occurs on the lower mountain site but at a much lower frequency (Table 2).

LOAM SITE.—Soils of this site are of the Bickmore family (loamy-skeletal, mixed Argic Pachic Cryoborolls), 50–100 cm to bedrock. They are moderately deep and well drained and are limited to the flat mountain top and gentle, concave slopes. An elevational stratum of the plant community occurs about 2,865 m (9,400 ft), with subalpine big sagebrush (*Artemisia tridentata* ssp. *vaseyana* form *spiciformis* Osterh.) dominant in the subalpine loam site above 2,865 m and mountain big sagebrush [*Artemisia tridentata* ssp. *vaseyana* (Kydb.) Beetle] dominant in the high mountain loam site below 2,865 m. Kings Fescue [*Hesperochloa kingii* (Piper) Rydb.] is the most conspicuous grass in the subalpine site. Mutton grass [*Poa fendleriana* (Steud.) Vasey] is also abundant. Idaho fescue (*Festuca idahoensis* Elmer) and Kentucky bluegrass (*Poa pratensis* L.) are abundant grasses, and yarrow (*Achillia lanalosa* Nutt.) and orange sneezeweed (*Helenium hoopsii* Gray) are abundant forbs in both sites. Tailcup lupine (*Lupinus caudatus* Kellogg) is an important component at the high mountain loam site. White locoweed occurs at a relatively high frequency (22%, Table 2) on the subalpine loam site but is only rarely encountered in the high mountain loam site.

White Locoweed Density

Density of white locoweed was greatest on

TABLE 2. Percentage frequency of occurrence of species and standard errors of the means (±) on four ecological sites on the Raft River Mountains.

	Subalpine windswept ridge	Mountain windswept ridge	Subalpine loam	High mountain loam
White locoweed	50 ± 4	15 ± 1	22 ± 4	6 ± 3
Yarrow	22 ± 9	3 ± 2	65 ± 7	33 ± 7
Rose pussy toes	5 ± 2	13 ± 8	18 ± 2	10 ± 7
Buckwheat	2 ± 1	6 ± 6	18 ± 4	11 ± 4
Sneezeweed	0	0	18 ± 11	13 ± 4
Aster	0	1 ± 1	0	8 ± 4
Tailcup lupine	0	0	0	26 ± 7
Cinquefoil	6 ± 3	0	1 ± 1	
Fleabane daisy	28 ± 5	30 ± 10	2 ± 1	
Hoods phlox	24 ± 6	42 ± 10	6 ± 1	6 ± 3
Mountain big sagebrush	0	0	0	48 ± 8
Subalpine big sagebrush	1 ± 1	0	47 ± 6	0
Low sagebrush	0	46 ± 23	0	1 ± 1
Alpine sagebrush	20 ± 4	16 ± 6	0	0
Rabbitbrush	2 ± 1	1 ± 1	3 ± 2	4 ± 2
Idaho fescue	7 ± 9	0	35 ± 23	25 ± 9
Kentucky bluegrass	1 ± 1	0	26 ± 3	32 ± 6
Mutton grass	41 ± 3	13 ± 6	34 ± 9	16 ± 7
Sandberg bluegrass	65 ± 4	38 ± 4	24 ± 1	12 ± 5
Western wheatgrass	30 ± 6	10 ± 9	23 ± 10	22 ± 6
Kings fescue	2 ± 1	0	18 ± 1	9 ± 4
Junegrass	5 ± 2	16 ± 10	4 ± 2	3 ± 2
Bluebrush wheatgrass	26 ± 6	46 ± 24	3 ± 3	11 ± 4
Wheatgrass	0	0	1 ± 1	23 ± 10
Columbia needlegrass	0	0	0	6 ± 4
Elk sedge	2 ± 2	0	9 ± 2	7 ± 2

the subalpine windswept ridge site, with 9.2 plants/m^2 (Table 3). Density declined 47% on the same soil but below 2,380 m on the mountain windswept ridge site. Diverse topography prevented gradient sampling of white locoweed at descending elevations.

White locoweed is an important forb on the deeper Bickmore soils on the subalpine loam site above 2,865 m. However, its density is 60% less than on the subalpine windswept ridge site (Table 3). White locoweed plants on the subalpine windswept ridge site were smaller in size (leaflets 10–12 cm compared to 20 cm long) than on plants on the subalpine loam site. However, white locoweed contributed 38% to the total standing crop on the subalpine windswept ridge site compared to 12% of the standing crop on the subalpine loam site (Table 4).

There was a fairly strong line of demarcation in white locoweed density between the subalpine and high mountain loam sites. White locoweed overlapped slightly into the higher reaches of the high mountain loam site (0.8 plants/m^2), but it disappeared from the plant community below 2,740 m.

TABLE 3. Mean white locoweed density and percentage of plants that are juvenile and standard errors of the means (±) for four ecological sites on the Raft River Mountains.

Ecological site	Density (plants/m^2)	Juvenile (%)
Subalpine windswept ridge	9.2a[1] ± 0.63	27.6 ± 2.24
Mountain windswept ridge	4.3b ± 1.42	16.3 ± 6.35
Subalpine loam	3.8bc ± 0.87	20.2 ± 4.33
High mountain loam	0.7c ± 0.28	15.5 ± 7.81

[1]Means followed by the same letter are not significantly different as determined by Duncans multiple range test ($P < .05$).

The preferred habitat of white locoweed appears to be the shallow, subalpine windswept ridge ecological site along the top and ridges of the mountain (Fig. 1), but it is less dense on the subalpine loam and lower mountain windswept ridge sites. Elevation and soils appear to exert a strong influence on its density and restriction to the top of the Raft River Mountain.

Change in Density Over Years

Density on the subalpine windswept ridge

Fig. 1. Ecological sites on which white locoweed occurs on the Raft River Mountains. Subalpine windswept ridge = SAR, mountain windswept ridge (low sage) = LSR, and subalpine loam = SAL.

site in the Rosevere pasture remained fairly constant (Table 5). The slope of the regression did not differ significantly from 0. Density of white locoweed on the subalpine loam site declined linearly between 1981 and 1986 ($r = -.93$), and the slope of the regression differed significantly from 0 ($P = .006$).

There was low correlation ($r = -.37$) between winter moisture accumulation or growing season precipitation, and locoweed density on either site (Table 6). Total precipitation may be much different from effective precipitation due to wind movement and snowdrift accumulation. Most of the snow on the subalpine windswept ridge was probably blown off and accumulated elsewhere, creating a fairly constant, limited source of soil moisture. The snowdrifts on the subalpine loam site would be variable from year to year depending on the particular wind patterns.

Discussion

The integrative effects of elevation, soil, and, perhaps, land form appear to restrict white locoweed to the top and windswept ridges of the Raft River Mountains. On the two windswept ridge ecological sites, white locoweed appears to have adapted a stress-tolerant survival strategy characterized by plants of arctic and alpine habitats (Grime 1977). The principal stresses are low temperatures, desiccating effects of strong winds, intense solar radiation, and mineral nutrient stress arising from low microbial activity in the soil (Grime 1977).

The extreme environmental stresses on the windswept ridge limit the presence of the more robust and competitive species (Grime 1977) such as mountain big sagebrush, Kentucky bluegrass, Kings fescue, and *Agropyron* species. White locoweed and other species on this site, while probably not more competitive than the robust species, are better able to withstand the environmental stresses. White locoweed on this site is much smaller, but more dense, than it is on the subalpine loam site, which is consistent with other observations of life forms of plants adapted to

TABLE 4. Standing crop (kg/ha) of forage classes and standard errors of the means (±) on high mountain subalpine loam and subalpine windswept ridge ecological sites in Rosevere pasture in 1985 on the Raft River Mountains.

Site	Grass	Forb	Sage	Loco	Total
Subalpine loam	465 ± 99	172 ± 24	0	89 ± 32	726
Subalpine windswept ridge	223 ± 37	62 ± 13	31 ± 15	147 ± 30	463

TABLE 5. Density of locoweed (plant/m^2) and standard errors of the means (±) on two ecological sites in Rosevere pasture on the Raft River Mountains. Probability of significant regression (P) between locoweed density and years, and correlation coefficient (r) are also given.

Year	Subalpine loam	Subalpine windswept ridge
1981	18.2 ± 1.55	13.1 ± 1.12
1982	11.2 ± 0.95	12.7 ± 1.09
1983	7.8 ± 0.67	9.9 ± 0.84
1984	6.4 ± 0.54	13.0 ± 1.11
1985	5.0 ± 0.43	10.3 ± 0.88
1986	3.4 ± 0.32	9.8 ± 0.91
P	0.006	0.13
r	−.93	−.67

nutrient-poor and stressful environments (Tilman 1985, Grime 1977). White locoweed is one of the first species to commence growth in the early spring; it remains green and succulent throughout the summer and is still green when covered by snow in the fall. It is also one of the more tolerant species to abnormal freezing temperatures during the growing season. On 5 and 6 July 1986, an abnormal cold front moved through the region. Temperatures at the nearest meteorological weather recording station at Grouse Creek (20 km west and 800 m below the study site) dipped below freezing on those two days. Temperatures at the study site must have been extremely low because most of the vegetation was frozen and turned a straw color. The flowers of white locoweed that were in bloom were frozen and aborted, but the leaves remained green and continued to grow.

The shallow, rocky habitat favored by white locoweed on the Raft River Mountains is similar to the coarse soils and dry habitat of white locoweeds described by Payne (1957) on the plains and foothills of the Rocky Mountains in Montana. The most important factor influencing its occurrence and density is the presence of coarse fragments in the soil. Payne (1957) speculated that the coarse fragments provide an interface for water percolation and accumulation. The long tap root could tap this deep, stored water and flourish in a harsh, xeric environment. The ability to tap deep-water storage in rocky soil, combined with tolerance of environmental stresses, may create a unique niche for white locoweed in the windswept ridge ecological site on the Raft River Mountains.

White locoweed is a minor species on the subalpine loam ecological site where it appears to exhibit a temporal or opportunistic survival strategy. Its density was extremely high in 1981 but declined during the remainder of the study. The decline did not appear to be related to precipitation. Other locoweed species exhibit large population fluctuations (Ogden et al. 1987). Population outbreaks may occur and dominate extensive areas for one or two years and then die off until the next time environmental conditions are favorable (James et al. 1968, Marsh et al. 1919, Ralphs and Bagley 1988). White locoweed is more stable than other locoweed species, but it does experience significant fluctuations in plant density (Marsh 1909).

TABLE 6. Winter and growing season precipitation recorded near the study site on the Raft River Mountains in northwestern Utah.

Season	Year 1981	1982	1983	1984	1985	1986
	Precipitation (cm)					
Winter accumulation[a]	46	91	91	70	47	59
Growing season[b]	1.5	10	18	7	5	5

[a]Snow course located 4 km west of and 100 m lower than study site. Accumulation of precipitation as of April 1 each year.
[b]Cumulative monthly precipitation June–August collected at Snowville, 48 km east of and 1,200 m below study site.

White locoweed seed have hard, impermeable seed coats and remain viable and in great abundance in the soil for many years (Ralphs and Cronin 1987). Germination rate in the laboratory (Ralphs and Cronin 1987, Ziemkiewicz and Cronin 1981) and in field trials (Payne 1957) is very low. This may be an ecological advantage, since a large, dormant seed reserve is retained in the soil to permit exploitation of favorable environmental conditions (Harper 1967). The opportunistic germination and establishment cycle of white locoweed may allow it to successfully compete in nutrient-rich, deep, subalpine loam ecological sites under conditions of relaxed competition.

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