GROWTH AND DEVELOPMENT OF SNOW BUCKWHEAT (*ERIOGONUM NIVEUM*) ON XERIC MINE SPOILS OF AN ABANDONED URANIUM MINE IN EASTERN WASHINGTON[1]

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Abstract: Snow buckwheat (*Eriogonum niveum*) is a native of the steppe region of the northern intermountain region in the Pacific Northwest. The habitat types in which this species is abundant represent some of the most xeric environments of the region. The species is an important dietary plant to wildlife (elk, deer, and birds) and has a vigorous colonizing ability. The Soil Conservation Service Plant Materials Center at Washington State University, Pullman, WA, developed and released an accession of 'Umatilla' snow buckwheat as conservation plant material for use in rangeland rehabilitation, wildlife upland habitat improvement, and critical area stabilization. The plant is a half-shrub, growing to 7 dm under ideal conditions, but generally averaging 3-6 dm maximum canopy height with a spreading canopy of 3-9 dm. A soil amendment and mulching study on xeric mine spoil sites was started in 1991 to determine the suitability of this species for use in native plant revegetation efforts on reconfigured and resoiled mine spoils. By the end of the 1993 growing season, 87% of the original plants had survived. Composted sewage sludge amendment at rates of 13.45, 26.9, and 53.8 t/ha (overdry weight) combined with mulch covers enhanced canopy development and reproductive vigor of the plants. Seedling establishment around parent plants is most evident on treatments with no mulch and high application rates of composted sewage sludge. Mulching with woodchips substantially reduces seedling establishment, suggesting that site amelioration to promote stand development of this species must consider soil surface characteristics created by the treatment process.

Additional Key Words: mine spoil revegetation, drought-tolerant shrub, composted sewage sludge, woodchip mulching.

Introduction

A substantial amount of the hard rock mining in the state of Washington occurs within forested areas. The forests of these areas represent vegetation types typical of the temperate xerophytic and mesophytic forest regions. Soil moisture is primarily recharged annually by winter rain and snow which varies from 460-1,000$^+$ mm per year depending on geographic location. Mining within these kinds of ecosystems presents some rather difficult reclamation problems in terms of the hydrology and the complexity of microsite mosaics created by the disturbance. Commonly, the disturbance of stratigraphy creates highly permeable, deep mine spoil deposits, and radical changes in microtopography and relief. These changes commonly result in more xeric surface conditions than normal. Under these conditions, revegetation strategies emphasizing native plant re-establishment may need to consider species more adapted to drier habitats than the native species that previously occupied the sites. Selection of species, however, does not preclude the use of native species of the *area* (not specific to the original site) to revegetate and potentially establish advanced stages of native vegetation succession on the reclaimed site.

The purpose of this study was to evaluate snow buckwheat (*Eriogonum niveum*) for use in

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revegetating droughty site conditions created by mine spoil deposition in forest areas of the inland Pacific Northwest. Snow buckwheat is a native of the steppe region of the northern intermountain region of the Pacific Northwest (fig. 1). The species range extends from southern British Columbia to extreme northern Nevada and across the Columbia Plateau between the Cascade Range of Washington and the Bitterroot Range of northern Idaho. All of the habitat types in which this species is found represent some of the most xeric environments of the region. The species has been identified as a common food component in diets of big game species in the Pacific Northwest (Burrell 1982, Tiedemann and Driver 1983). An accession of 'Umatilla' snow buckwheat was released by the Soil Conservation Service Plant Materials Center at Pullman, WA, for use in rangeland rehabilitation, wildlife upland habitat improvement, and critical area stabilization (Lambert 1991, 1992).

Generally the species is best adapted to precipitation zones of 170-380 mm, though the plant may be found in higher precipitation zones on sites with less effective moisture resulting from soil and/or topographic conditions.

Figure 1. An illustration of snow buckwheat (*Eriogonum niveum*) (*from Hitchcock et al. 1964, with permission*).

The plant is a half-shrub, growing to 7 dm under ideal conditions, but generally averaging 3-6 dm maximum canopy height with a spreading canopy of 3-9 dm. This species is drought tolerant, has a root system adapted to gravelly and rocky soils, and can colonize grass-covered surfaces of disturbed sites. Because of its winter persistent leaves, continual production of leaves throughout the summer, and extensive root system, the plant can potentially contribute significantly to the transpiration component of the water budget of disturbed moist sites. The plant is common within the ponderosa pine/bitterbrush (*Pinus ponderosa / Purshia tridentata*) zone at elevations within 150 m below the mine site. The soil materials of these natural habitat types are comparable in terms of moisture conditions to the mine spoil deposits of the study area.

The specific objective of the study was to measure the establishment and growth of plantings of snow buckwheat on mine spoil deposits to determine its adaptability to the higher moisture climate and response to composted sewage sludge amendments and mulching treatments of the mine spoil material.

Materials and Methods

Study Area

The study is being conducted on an abandoned, open-pit, hardrock uranium mine on the Spokane Indian Reservation, Stevens County, in east-central Washington. Precipitation at the site averages 450 mm per year, which falls primarily in the winter. The principal native vegetation of the area surrounding the mine is of the ponderosa pine / bluebunch wheatgrass (*Pinus ponderosa / Agropyron spicatum*) and ponderosa pine/snowberry (*Pinus ponderosa / Symphoricarpos albus*) plant associations. The mine lies within an ore body that is located in a metasedimentary formation, which contains substantial amounts of pryitic mica phyllite. Exposure of the pyrite has initiated acid rock drainage. The groundwater flow system and leaching characteristics of wastes at this mine could have significant effects on the quantity and quality of impounded and soil water and impact the quality of ground water leaving the mine site. Consequently, our revegetation and resoiling research at this site is focused on options for installation and on-site development of soil and vegetation covers that would provide long-term surface stability and act as deterrents to deep percolation of meteoric water to buried, acid-generating waste rock deposits.

Planting Design

Field plantings of six month old containerized snow buckwheat plants were established during July of 1991 with the aid of drip irrigation. Drip irrigation was not used after the fall of 1991. The plot area was first graded and ripped with heavy equipment to break up compacted mine spoil, then topdressed with 2 dm of clay subsoil designated for eventual use in the reclamation of the mined area. Three rates of composted sewage sludge (13.45, 26.9, and 53.8 t/ha, oven-dry weight metric tons) were combined with a 5 cm deep, topdressed woodchip mulch to create eight treatments in a randomized complete-block design (table 1). The chemical character of the composted sludge was as follows: pH 5.2, NO^3-N 5.1 ug/g, NH^4-N 95.6 ug/g, %N 2.32, %C 30.14. No additional nitrogen was added to the sludge to balance the carbon/nitrogen ratio. Ten containerized seedlings were planted per replication at 6 dm spacings within a 1.8x3.6 m plot in which the soil amendment treatment was applied.

Table 1. Percent survival of snow buckwheat (*Eriogonum niveum*) plants on amendment treatments of mine spoils in 1992 and 1993.

	% Survival	
Treatments	1992	1993
No mulch, no compost	94	91
Mulch, no compost	92	92
No mulch, 13.45 t/ha[1]	96	85
Mulch, 13.45 t/ha	90	85
No mulch, 26.9 t/ha	90	88
Mulch, 26.9 t/ha	82	78
No mulch, 53.8 t/ha	95	95
Mulch, 53.8 t/ha	88	83

[1] Oven-dry weight composted sludge

Measurements and Analyses

Measurement and evaluation of the plantings were initiated in 1992. Survival of plants and seedling establishment was assessed for each treatment at the end of the growing season each year. Canopy area and volumes, number of floral bolts per plant, and average maximum height of the vegetative and floral components of canopies were made at the time of full floral development in late August to early September. Canopy areas of both the vegetative part of the canopy and floral component of the plants were made by measuring the longest diameter of the canopy ellipse and the longest perpendicular diameter to this long axis. Within this elliptical area, the coverage of live canopy was estimated. The estimate of canopy area for each plant was then calculated as the area of the ellipse minus the percentage of unoccupied space and expressed in dm^2. Floral canopy area was estimated in the same manner. Volume (dm^3) estimates of the vegetative canopy were based on an elliptical cylinder by incorporating an average maximum height dimension into the canopy area calculation. For the floral canopy component, the frustum of an elliptical cone was used to determine volumetric space occupied by that portion of the canopy occupied solely by flowering stems (Mawson et al. 1976). Canopy volume is a multidimensional measure of canopy structure that may provide additional insight about species dominance of plant communities (Zamora 1981). Statistical analyses of the data were accomplished with the Tukey HSD simultaneous pairwise mean comparison method in the Systat Statistical Program (SYSTAT 1992).

Results and Discussion

Growth Pattern

The developmental pattern of both vegetative and floral growth of snow buckwheat over the two full growing seasons of observation did not differ between the eight treatments. Snow buckwheat is indeterminate in its floral and seed development, producing flowers and mature seed over an extended period of time. The enriched soil nutrient conditions of some treatments may have accentuated this attribute in some plants by prolonging the period of floral development.

Snow buckwheat has an herbaceous but winter-persistent leaf canopy that develops from a base of woody prostrate stems. Growth of the plant begins in March or early April and accelerates to a maximum leaf area in the canopy by the first part of July. Floral bolt initiation may be evident in late May or early June but generally does not accelerate until after the majority of the maximum leaf area has developed in the canopy. It is at this point that enriched habitats of plants may stimulate an accelerated rate of floral stem initiation. With the rapid growth of floral stems, leaf area significantly declines with older leaves senescing and dropping out of the functional leaf pool of the canopy. The carbon balance within the plant shifts dramatically to support floral development, and remains in this status until after seed shatter, which occurs in September. There is evidence within the genus that the floral stems actively carry on photosynthesis, replacing that particular role of leaves during the reproductive phase of the annual growth cycle (Smith and Osmond 1987, Osmond et al. 1987). The floral stems of snow buckwheat do have a significant number of leafy bracts, which may add to the photosynthetic capability of the stem. Following seed shatter, growth modules, which form the coming year's canopy growth, are rapidly initiated before fall/winter temperatures preclude further meristem development. Some proportion of the larger and later developing leaves of the current year's growth will persist through the winter to form a pool of leaf tissue that will be photosynthetically active at the start of next year's growth cycle.

Survival of Plants

Survival of the container grown plants from 1991 into the 1992 growing season averaged 96% across all treatments. By the end of the 1992 growing season, an average of 91% of the plants had survived across all treatments (table 1). By the end of the 1993 growing season, only an additional 4% of the plants had been lost. Some plant loss was due to browsing and uprooting of plants by elk. No statistically significant differences were evident between treatments in either year.

Canopy Structure

Average total canopy volume per plant increased between 1992 and 1993 in seven of the eight treatments, but was not found to be statistically different between the two years across the treatments (fig. 2). During the first year of establishment in 1991, plants developed substantially more vegetative canopy than floral canopy. This vegetative canopy overwintered into the 1992 growing cycle, contributing significantly to the vigorous establishment of the plants. The vegetative volume component of the canopies, however, changed very little between 1992 and 1993 when the plants entered into a typical reproductive phase. The floral volume component of the canopy did demonstrate a greater degree of increase between 1992 and 1993 indicating the degree to which the plants were allocating greater resources to the reproductive process. In 1992, there was a stronger tendency for treatments with mulch covers and higher rates of composted sewage sludge amendment to produce statistically greater canopy volumes than treatments with lesser rates of amendment with or without mulching. In 1993, the number of significant differences between treatments declined with the most evident difference being between the mulch, no compost amendment and the mulch, high compost amendment treatments.

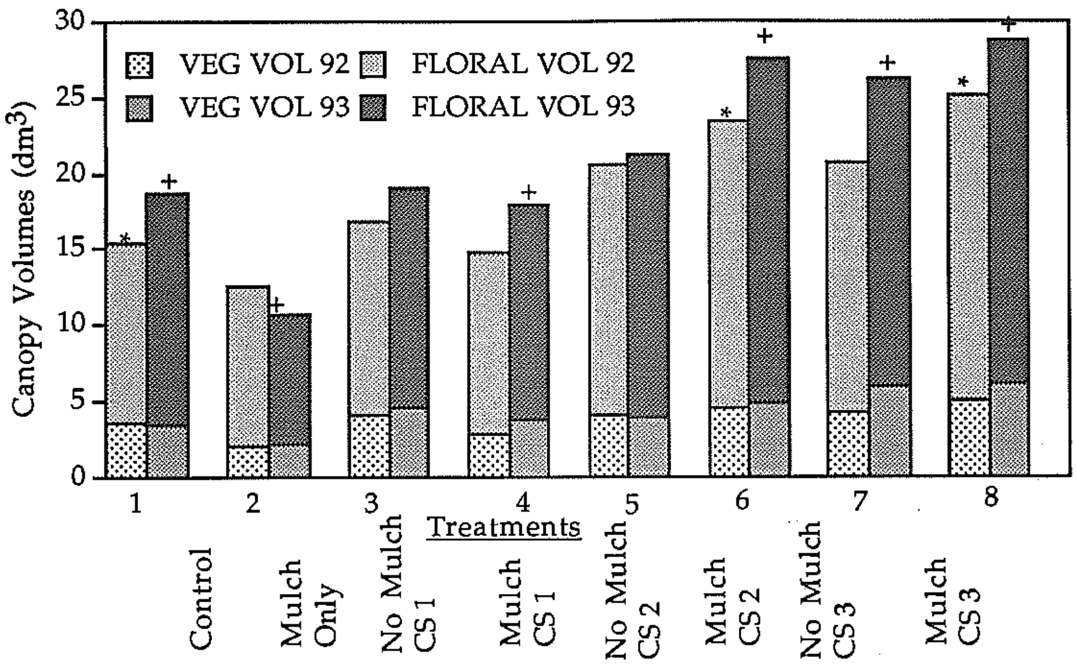


Figure 2. Average vegetative and floral canopy volumes of snow buckwheat (*Eriogonum niveum*) among soil amendment treatments in 1992 and 1993. Composted sludge levels, CS1 = 13.45 t/ha., CS 2 = 26.9 t/ha., CS 3 = 53.8 t/ha. (*)Treatments 1, 2, and 4 differ from treatments 6 and 8; (+)Treatment 2 differs from treatments 6, 7, and 8 at the 0.1 probability level using Tukey HSD simultaneous pairwise mean comparisons.

Both vegetative and floral canopy area showed little change between years although some significant differences were discernible between some treatments within years (fig. 3 and 4). Canopy area was distinguished from other canopy measures as a means of identifying lateral canopy expansion on a yearly basis. Since snowy buckwheat appears to be self limiting in terms of height, lateral expansion of the canopy should dictate changing canopy structure and leaf area. Average height of the vegetative canopy, depth of the floral component of the total canopy, and total height did not significantly differ between treatments and differed only to a small degree between years (table 2). In general, the trend in average canopy area was from smaller average canopy areas in treatments with no compost amendment or low rates of compost to larger canopy areas with high rates of compost amendment with mulch covering (fig. 3 and 4).

Reproductive Vigor

Reproductive vigor of the plants, as measured by the number of floral stems per plant, was similar in response to treatments as measured with canopy volume and area (fig. 5). Generally, plants averaged fewer flowering stems in treatments with no compost or low rates of compost amendment than plants growing in higher rates of compost amendment with mulch covering.

Seedling Establishment

Seedling establishment was evident among the eight treatments at the start of the 1993 growing season. No seedlings were observed on the treatment sites prior to persistent snow cover the previous

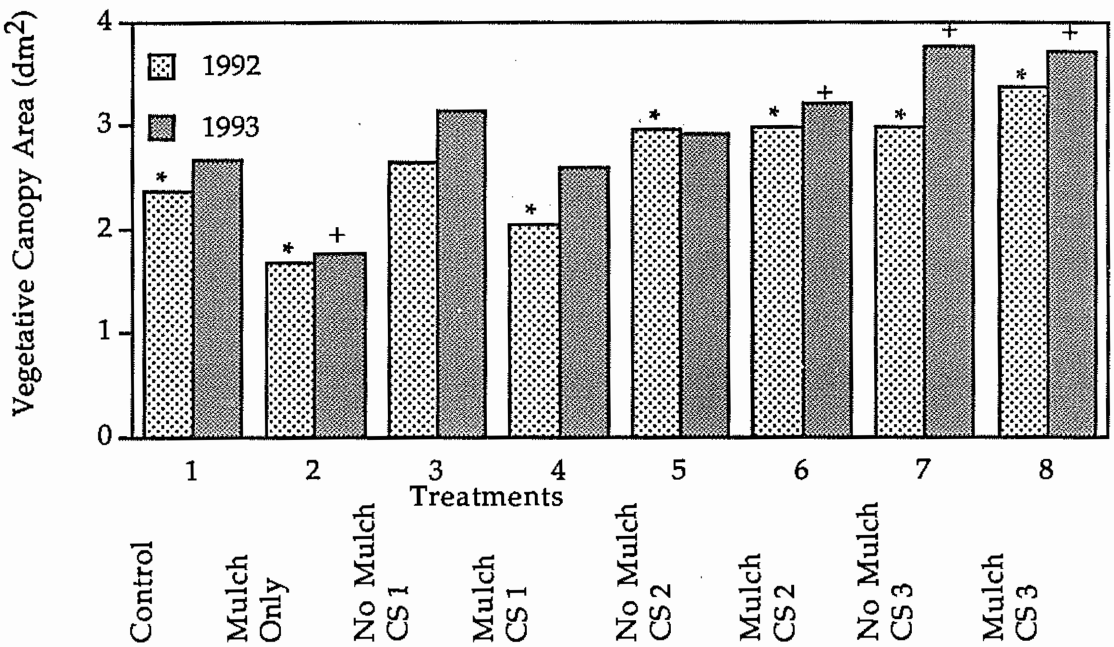


Figure 3. Vegetative canopy areas of snow buckwheat (*Eriogonum niveum*) in 1992 and 1993 among soil amendment treatments. Composted sludge levels, CS1 = 13.45 t/ha., CS2 = 26.9 t/ha., CS3 = 53.8 t/ha. (*)Treatments 1 and 4 differ from treatment 8, treatment 2 differs from treatments 5, 6, 7, and 8; (+)treatment 2 differs from treatments 6, 7, and 8. Significant differences at the 0.1 probability level, Tukey HSD simultaneous pairwise mean comparisons.

Table 2. Mean heights of canopy components of snow buckwheat (*Eriogonum niveum*) plants on amendment treatments of mine spoils in 1992 and 1993.

	Mean Height (cm) of Canopy Component					
	Vegetative		Floral		Total	
Treatment	1992	1993	1992	1993	1992	1993
No mulch, no compost	13	11	25	27	38	38
Mulch, no compost	10	11	25	22	35	33
No mulch, 13.45 t/ha[1]	13	13	26	26	39	39
Mulch, 13.45 t/ha	12	12	26	25	38	37
No mulch, 26.9 t/ha	13	12	28	28	40	40
Mulch, 26.9 t/ha	13	12	27	27	40	40
No mulch, 53.8 t/ha	12	13	26	26	39	39
Mulch, 53.8 t/ha	13	14	27	27	40	41

[1] Oven-dry weight composted sludge

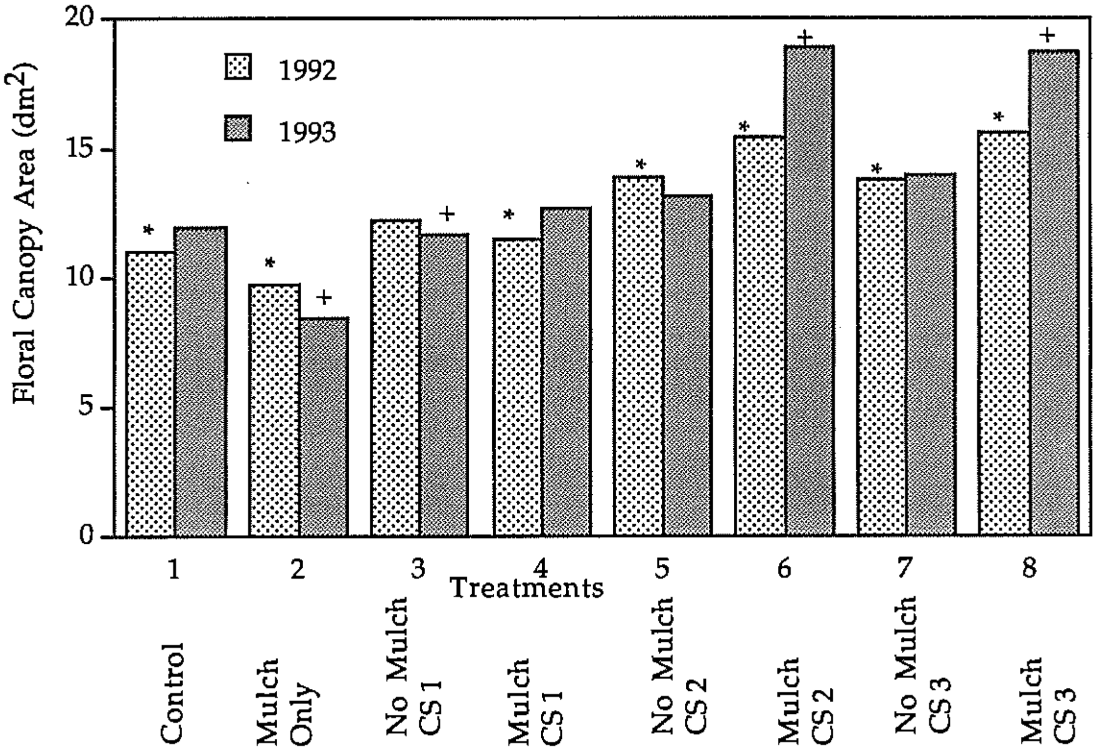


Figure 4. Floral canopy areas of snow buckwheat (*Eriogonum niveum*) in 1992 and 1993 amomg soil amendments treatments. Composted sludge levels, CS1 =13.45 t/ha., CS2 = 26.9 t/ha., CS3 = 53.8 t/ha. (*)Treatments 1 and 4 differ from treatments 6 and 8, treatment 2 differs from treatments 5, 6, 7, and 8; (+)treatment 2 differs from treatments 6 and 8, treatment 3 differs from treatment 6. Significant differences at the 0.1 probability level, Tukey HSD simultaneous pairwise mean comparisons.

fall so germination may have taken place under a heavy snowpack or very rapidly following snowmelt. Germination trials with this species suggest that if germination does not take place within days following seed deposition on the soil surface, secondary dormancy develops and the seed becomes a dormant element of a long-lived seed bank in the soil until disturbance occurs. Seedling establishment appeared to be influenced by surface conditions within the treatment site (table 3). Seedling establishment was inhibited by mulch cover. However, the higher rates of compost amendment (26.9 and 53.8 t/ha) significantly enhanced seedling establishment. After incorporation, sludge residues are still evident on the surface of the plots. These residues darken the soil surface, produce a considerable range of soil surface textures, and contribute to a diverse mosaic of surface conditions and microtopography. These conditions may contribute to an enhanced environment for seedling establishment.

Conclusions

Survival of snow buckwheat on amended mine spoils exceeded expectations after two growing seasons with an average loss of only 13% of the plants among all treatment plantings in the experiment. Vegetative and reproductive growth of all plants was vigorous across all amendment treatments. Generally, composted sewage sludge amendment rates of 26.9 and 53.8 t/ha produced greater canopy growth and reproductive vigor among the plants. Since 1992 and 1993 were years of average to above

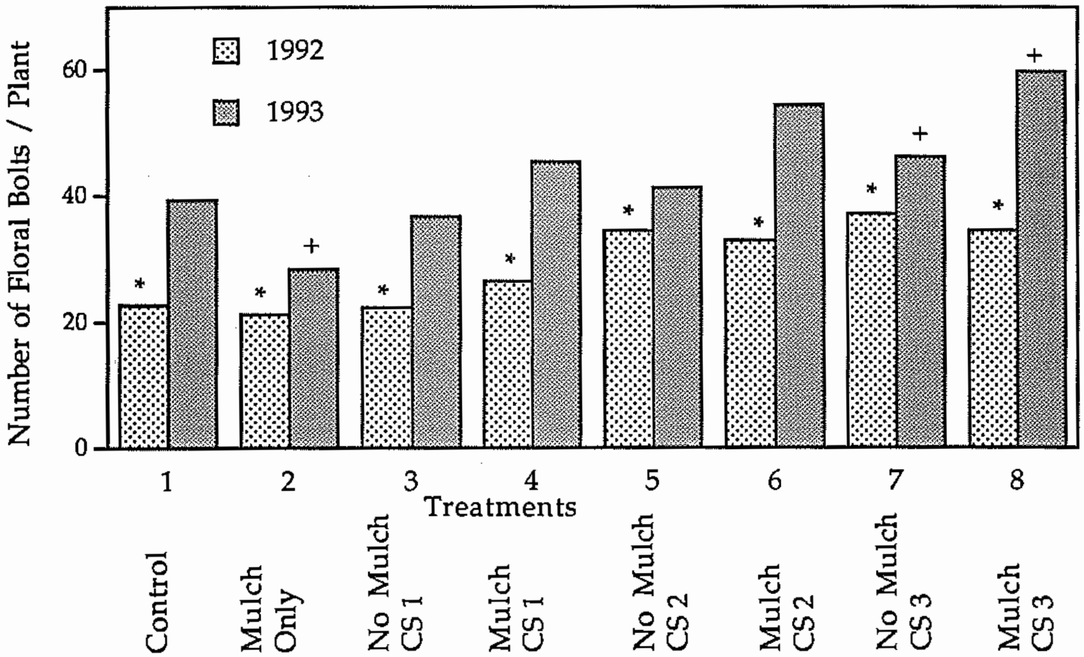


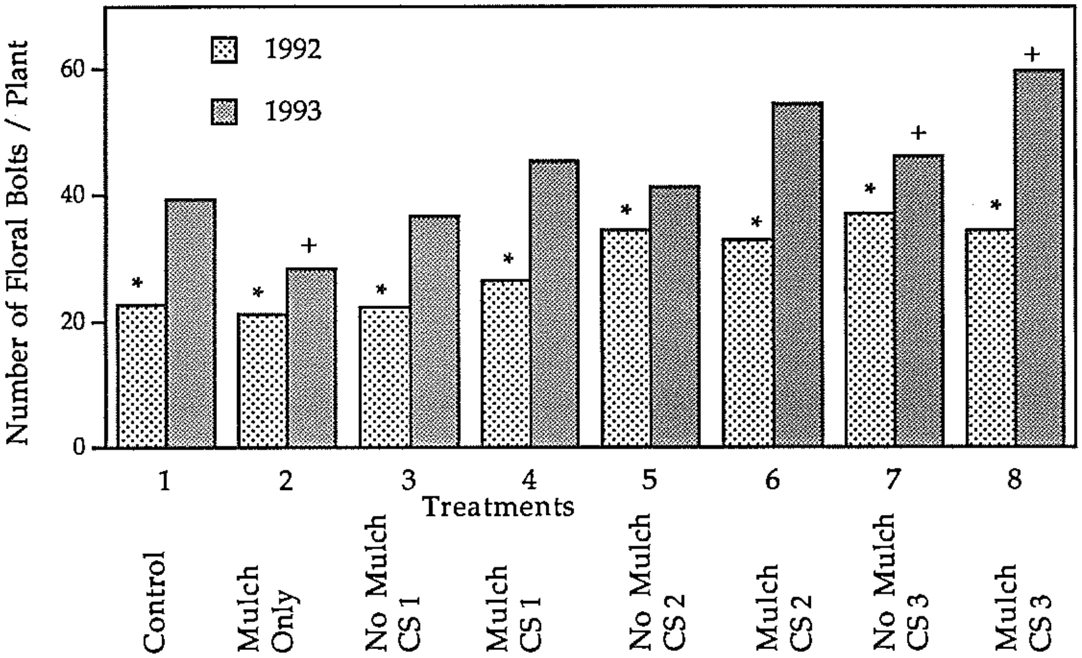
Figure 5. Average number floral bolts of snow buckwheat (*Eriogonum niveum*) per plant in 1992 and 1993 among soil amendment treatments. Composted sludge levels, CS1 = 13.45 t/ha., CS2 = 26.9 t/ha., CS3 = 53.8 t/ha. (*)Treatment 1 and 3 differ from treatments 5, 7, 8, treatment 2 differs from treatments 5, 6, 7, 8, treatment 4 differs from treatment 7; (+)treatment 2 differs from treatments 6 and 8. Significant differences at the 0.1 probability level, Tukey HSD simultaneous pairwise mean comparisons.

average precipitation, the mulch treatment probably did not contribute substantially to an improved environmental microsite condition for each plant. The enriched soil N condition however, likely caused the increase in canopy development and reproductive vigor. Seedling establishment was significantly reduced by the mulching treatment but enhanced by the higher rates of composted sewage sludge

Table 3. Percent snow buckwheat (*Eriogonum niveum*) seedling occurrence on amendment treatments of mine spoils in 1992 and 1993.

Treatments	Seedling Occurrance		
	Absent	P[1]	A[2]
No mulch, no compost	63	17	20
Mulch, no compost	82	14	4
No mulch, 13.45 t/ha[3]	60	30	10
Mulch, 13.45 t/ha	79	21	0
No mulch, 26.9 t/ha	59	16	25
Mulch, 26.9 t/ha	82	18	0
No mulch, 53.8 t/ha	38	25	37
Mulch, 53.8 t/ha	80	16	4

[1] P= <10 seedlings within 3 dm radius of plant.
[2] A = >10 seedlings within 3 dm radius of plant.
[3] Oven-dry weight composted sludge



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