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LEGUME SPECIES FOR EROSION CONTROL IN THE CENTRAL SIERRA NEVADA MOUNTAINS

ABSTRACT

Between the years 1989 and 1994, a series of replicated field trails were conducted in the Lake Tahoe Basin to identify species of legumes which could be established on critical area planting sites as effective, low maintainence forms of ground cover on high elevation sites. Results of this evaluation have been incorporated into the Field Office Technical Guide and are utilized in development of Construction Specifications for revegetation treatments on cut slopes and other bare earth areas.

Introduction

This report documents the evaluation of direct seeding of legume species on decomposed granitic soils in the Lake Tahoe Basin. The purpose of this evaluation was to identify species of legumes and horticultural treatments for potential use as effective, low maintenance plants for erosion control in the Lake Tahoe Basin and other high altitude areas. Results of this evaluation have provided direction in development of construction specifications for revegetation treatments on cut slopes and other bare earth situations. It has been implied that application of these results may extend to locations outside of the Lake Tahoe Basin where soils derived from decomposed granite exist.

A Standard Agreement was executed in 1989 among Caltrans and the USDA Natural Resources Conservation Service (formerly the Soil Conservation Service). Field trials were established in the fall of 1989, 1990, 1992, and 1993. Due to below average precipitation during 1989 thru 1994 which may have adversely affected the results, this Agreement was extended in 1991 and again in 1993.

Field trials were conducted in two phases. The first phase of field trials were established to identify those species of legumes that would successfully germinate and maturate when directly seeded into freshly disturbed soils. To determine this, 8 foot by 8 foot plots were constructed on freshly disturbed soils. Each plot was then direct seeded with a single species. To assess the effects of varying mulch rates and soil amendments, plots were replicated for a total of three plots per species.

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Each species was subjected to three horticulture treatments:
1) direct seeding and fertilizing without a top dressing of mulch;
2) direct seeding, fertilizing, applying 2 tons/acre straw mulch; and
3) direct seeding, covering with 2 tons/acre straw mulch, and applying a soil conditioner (dolomitic lime).

This was a broad or "shotgun" analysis of legume species. All species which could be obtained commercially or otherwise collected locally were included in the evaluation (See Table 1).

The second phase of this evaluation focused on those species which germinated and persisted to a degree of maturity consistent with the first years growth for that species. Each candidate species (See Table 2) was subjected to five treatments:
1) direct seeding, fertilizing and straw mulching at 1 ton/acre;
2) direct seeding, fertilizing, and straw mulching at 2 ton/acre;
3) direct seeding, fertilizing, and straw mulching at 3 ton/acre;
4) direct seeding, fertilizing, and straw mulching at 4 ton/acre;
5) direct seeding with both legumes and perennial grasses, fertilizing, and straw mulching at 2 tons/acre; and
6) direct seeding legumes and native shrubs, fertilizing, covering with native topsoil, and straw mulching at 2 tons/acre.

All field trials in the first phase were established on level, disturbed ground. Trials established in the second phase were established on both flat, freshly disturbed soil and on a roadside cutslope of approximately 1.5:1 slope (1.5 feet vertical to one foot horizontal).

Legume seeds were pellet inoculated with species specific rhizobia when available. They were otherwise inoculated with a broad spectrum inoculant provided by Liphatech Inc. of Milwaukee, Wisconsin. While the bulk of the seed used in this evaluation were obtained through a variety of commercial sources, four species (Lupinus grayii, L. brewerii, L. sellus and L. fulcratus) were collected by NRCS staff within the Lake Tahoe Basin.

Seeding rates were based on the Pure Live Seed (PLS) content as established by the supplier. Rates were also based on consultation with Bob Slayback, NRCS Plant Materials Specialist (1). Those species or varieties lacking a purity or germination test within the previous six months were tested by the California Department of Food and Agriculture Seed Lab for germination and hard seed content.

Fertilizer used in this evaluation was 0-20-0 which was applied at the rate of 200 lbs/acre. This was supplemented with popcorn sulphur applied at the rate of 75 lbs/acre.

The staff of the Natural Resources Conservation Service, South Lake Tahoe Field Office constructed and monitored the field trails. With one exception, all plots were established in the Lake Tahoe Basin. Plots were established in the fall prior to the first winter snowfall. The results of the evaluation are incorporated in this report.

Field observations were made in the spring and summer following seeding the previous fall. Ground cover, plant density within plots and a qualitative observation of plant vigor were obtained per species per treatment.

Ground Cover was quantified according to the following criteria:

Excellent - >75% ground cover at maturity
Good - 25% to 75% ground cover at maturity
Poor - <25% ground cover at maturity

Plant density was determined by actual count of plants within the 64 square foot plots. The results of the counts are presented in Table 2.

This report presents the findings of the trials, as well as recommendations for construction specifications and further work.

Results - Phase 1

The first phase of this evaluation was conducted in 1989 and replicated at another south shore location in 1990. Results of the 1989 trial were less than anticipated. The first years activity resulted in a 62 percent germination rate among species among treatments. Of the 69 species and varieties evaluated (See Table 1), only 11 produced seedlings which persisted beyond September 30 (See Table 2). Only three species germinated and persisted under all three levels of treatments.

The 1990 trial provided little significant data due to poor germination. The observed germination rate in this trial was less than 5 percent among species among treatments. No plants were observed in plots after July 31. Average annual precipitation during 1989 and 1990 were 74 percent and 75 percent respectively (2). Two years of below average precipitation may responsible for the less than desired germination and survival of species within the replicated trials. Due to the poor results of the 1990 trial, the results of the 1989 and 1990 trials could not be statistically compared.

The first level of treatment in Phase 1, direct seeding and fertilizer without a mulch top dressing, exhibited germination approximately 2 to 3 weeks earlier than the companion treatments which were treated with a top dressing of straw mulch. With three exceptions, seedlings in this treatment exhibited diminishing vigor as the season progressed. Presumably this is due to the lack of straw mulch which allowed the soil to lose moisture before adequate root development could occur.

Treatments 2 and 3, where straw mulch was applied at 2 tons/acre exhibited a greater number of species and varieties germinating, higher plant density within plots and better vigor. Surviving plants in these plots persisted well into the fall evaluation period. Two species, Sanguisorba minor and Trifolium fragarium (SCS251174) produced an infloresence with seeds within both treatments.

Data was insufficient to draw a conclusion of the effect of applying dolomitic limestone in Treatment 3. With few exceptions, plant density and vigor was observed to be greater overall in plots not treated with limestone.

TABLE 1. LEGUMES SUBJECTED TO INITIAL EVALUATION

SPECIES	PLS%	APPLICATION RATE (lbs/acre)
Astragalus cicer "Lutana"	90	15
A. cicer "Monarch"	90	15
Cassia fasiculata	45	5
Coronilla varia, "Chemung"	60	10
C. varia "Emerald"	75	9
C. varia "Penngrift"	72	9
Hedysarum boreale	36	9
Lathyrus sylvestris	78	6
L. alpestris	93	35
L. argentus	91	35
L. arizonicus	65	35
L. benthamii	95	35
L. brewerii	32	35
Lotus tenuis	58	27
L. corniculatus "Dewey"	76	27
L. corniaulatus "Cascade"	82	27
L. corniculatus "Georgia 1"	80	27
L. Scoparius	71	27
Lupinus albicaulis "Hederma"	90	35
L. albicaulis, common	96	35
L. albifrons	89	35
L. confertus	70	35
L. excubitus	57	35
L. formosus	48	35
L. fulcratus	52	35
L. greyii	28	35
L. luteus	84	35
L. nanus	98	35
L. neomexicanus	42	35
L. perennis	38	35
L. sellus	44	35
L. sericius	78	35
L. sparsiflorus	58	35
L. subcarnosus	44	35
L. texensis	78	35
L. truncatus	25	35
L. valicola	11	35
Medicago sativa "Emerald"	78	12
M. sativa "Ladak"	91	12
M. sativa "Ranger"	85	12
M. sativa "Vernal"	82	12

TABLE 1. LEGUMES SUBJECTED TO INITIAL EVALUATION - Continued

SPECIES	PLS%	APPLICATION RATE (lbs/acre)
M. sativa "Nomad"	76	12
Meliolotus alba	74	18
M. officialnalis "Madrid"	81	18
Onobrychis viviaefolia "Remont"	77	18
O. viviaefolia "Eski"	89	18
Petalosteum purpureum	65	18
Sanguisorba minor "Delar"	95	20
Trifolium alexandrium	54	27
T. cherleri "Yamina"	65	27
Trifolium fragarium (SCS204509)	38	27
T. fragarium (SCS230359)	52	27
T. fragarium (SCS250789)	39	27
T. fragarium (SCS251174)	42	27
T. fragarium (SCS251175)	65	27
T. fragarium (SCS251849)	50	27
T. fragarium (SCS284584)	41	27
T. fragarium (SCS297983)	32	27
T. fragarium (SCS325495)	51	27
T. fragarium "Salina"	95	27
T. hirtum "Wilton"	81	27
T.hybridum "Alsike"	85	27
T. repens "White Dutch"	88	27
T. subterraneum "Mt. Barker"	95	27
T. subterraneum (SCS9041007)	56	27
T. subterraneum (SCS9041013)	86	27
T. subterraneum "Seaton Park"	84	27
Vicia villosa	85	16

TABLE 2. GERMINATION OF LEGUMES BY TREATMENT, FIRST STRATA

SPECIES	TX1	TX2	TX3
Lotus corniculatus "Georgia 1"		60g	21g
Lupinus brewerii		1g	4g
Lupinus confertus	6p	14e	6e
Lupinus grayii		1e	5e
Lupinus sellus		6g	2p
Lupinus perennis		1g	
Onobrychis viviaefolia "Remont"	3p	3g	3g
Sanguisorba minor "Delar"		7e	10p
Trifolium fragarium (SCS250789)		5p	
Trifolium fragarium (SCS251174)		25g	10p
Trifolium hybridum "Alsike"	4p	44g	48e

Number of plants per 68 square foot plot. Letters indicate e = excellent vigor, g = good vigor, p = poor vigor.

Results - Phase 2

A total of five species were selected for further evaluation in the second phase of treatments. These were Lupinus confertus, L. sellus, Lotus corniculatus "Georgia 1", Sanguisorba minor "Delar" and, Trifolium hybridum "Alsike". This second phase of the evaluation process was implemented on a level, disturbed area near Myers, California in 1993, and replicated on a cutslope on Highway 89 north of Truckee, California in 1994.

The 1993 trial at Meyers was developed in the fall prior to a winter characterized by 165 percent of above average precipitation. All species germinated and persisted into the fall of 1994.

Two species exhibited sufficient plant density and vigor during this first year to indicate an adequate ground cover for erosion control purposes (> than 50 percent). These were Alsike Clover (Trifolium hybridum) produced 0.8 plants per square foot while "Georgia 1" Birdsfoot Treefoil (Lotus corniculatus) produced 1.4 plants per square foot.

"Delar" Small Burnet (Sanguisorba minor) exhibited promise early in the season producing 2.2 plants per square foot. While plant density remained high until the end of the season, plant cover (< 10 percent) and vigor diminished rapidly as the summer progressed. The airy, dispersed foliage of this upright plant accounts for the minimal ground cover it provides.

Insufficient ground cover (< 50 percent) resulted from Lupinus confertus and L. sellus. These also diminished as the season progressed. A follow-up inspection in the fall of 1994 exhibited decrease in plant density and vigor within all plots during the second year. Precipitation in 1994 was less than 60 percent of average.

The application rate of straw mulch was treated as a variable, where rates were varied between 1 and 4 tons/acre among treatments. Plant density and vigor was greatest with a straw application of between 1 and 3 tons/acre. A pronounced decrease in plant density occurred under an application of 4 tons/acre. A slight decrease in legume seedlings was noted within the interseeding treatments, which may be attributed to either alleopathy(3) or competition for moisture and nutrients(4).

Plots interseeded with perennial grass species (See Table 3.) exhibited a well developed ground cover comprised predominantly of grass. More interestingly, plots interseeded with shrubs (See Table 4.) produced a high density of shrub seedlings which persisted to the last evaluation in 1994. All three species of shrubs, Antelope Bitterbrush (Pursia tridentata), Sulphur Flower Buckwheat (Eriogonum umbellatum) and Big Sagebrush (Artemesia tridentata) were present and vigorous. Data taken in the fall of 1994 indicated four shrub seedlings per square foot when seeded at 40 lbs/acre. Seedling composition consisted of 65 percent Artemesia tridentata, var. vasyana; 30 percent Eriogonum umbellatum; and 5 percent Pursia tridentata. Seedling vigor in the fall remained excellent until the onset of dormancy.

The attempt to replicate these results on a cutslope in 1994 failed. Plots were established on a Caltrans cutslope on Highway 89 near Hobart Mills, California. Precipitation that year averaged 92 percent of average. The treatments applied within these plots were similar to those applied the previous year except for the straw mulch. Whereas barley straw had been applied throughout this evaluation, rice straw mulch had been applied by a private contractor in conjunction with Caltrans road improvements and revegetation work.

TABLE 3. PERENNIAL GRASS SPECIES AND SEEDING RATES

SPECIES	APPLICATION RATE LBS/ACRE
Agropyron trachycalum "Primar Slender Wheatgrass"	4
Festuca longifolia "Scaldis" Hard Fescue	3
Festuca longifolia "Durar" Hard Fescue	3

TABLE 4. SHRUB SPECIES AND SEEDING RATES

SPECIES	APPLICATION RATE LBS/ACRE
Pursia tridentata (Antelope Bitterbrush)	15
Eriogonum umbellatum (Sulphur Flower Buckwheat)	15
Artemesia tridentata var. vasyana (Mountain Sagebrush)	10

Conclusions and Recommendations

Direct seeding and establishment of legume species on decomposed granitic soils has proven to be a challenge regardless of associated horticultural treatments. The highly variable and below average precipitation years experienced during the course of this evaluation may be responsible for producing inconclusive data. This in itself may suggest that the successful establishment of legumes is dependant on the occurrence of adequate precipitation which is distributed throughout the growing season.

The application of a suitable mulch material is critical to the successful germination and establishment of seeded species. Two to three tons per acre of straw mulch appears to be the optimum rate. Rates of 0 to 1 ton per acre proved inadequate for retaining soil moisture for a longer period into the growing season. A general decline in germination and plant establishment was experienced under an application of 4 tons per acre. While barley and rice straw were utilized as mulches in this evaluation, the use and benefits of alternative mulches such as wood chips and pine needles should be further investigated.

Five species of legumes, Sanguisorba minor ("Delar" Small Burnet), Lupinus confertus, L. sellus, Lotus corniculatus ("Georgia 1" Birdsfoot Trefoil), and T. hybridum "Alsike", are believed to have merit for future evaluation. With the exception of Small Burnet, all have exhibited good germination and persistence under proper conditions. Small Burnet may have application as a short term ground cover where persistence is not a desired trait. Commercial seed availability does not appear to pose a problem for any of the species.

The commercial availability of "Georgia 1" Birdsfoot Trefoil seed; success in germination and establishment; and long term persistence identifies this legume as an outstanding candidate for inclusion into high elevation seed mixtures in DG soils. This variety, with an upright and spreading growth habit, has since been successfully incorporated into construction specifications in the Lake Tahoe Basin. The success of this plant is noteworthy and complementary to another highly successful legume, Astragalus cicer ("Lutana" Cicer Milkvetch), which has a long history of use in erosion control in the Lake Tahoe Basin. Further evaluation needs to be conducted to determine the appropriate seeding rate for Georgia 1.

It is also recommended that further study be engaged to determine the feasibility of direct seeding of native shrubs. The significance of successful direct seeding of native shrubs is noteworthy from both an environmental and economic perspective. Simply put, the direct seeding of shrubs on highway cut slopes in the Sierra Nevada may produce the desired vegetative composition at a cost comparable to that of grass seeding. The established shrubs would produce a more effective and long term cover for erosion control than many present seeding treatments.

References

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