Revegetation of serpentine soils: difficult but not impossible

Richard F. Smith □ Burgess L. Kay

Disturbed soil caused by gold mining in Lake County, California.

California serpentine soils are increasingly being disturbed by attempts to remove precious metals or to develop energy resources, and successful revegetation to control erosion is difficult because of poor plant growth. Growth is generally sparse, because soils derived from serpentine (the California state rock) have very little calcium and an abundance of magnesium. Unlike most other soils, which usually have calcium/magnesium ratios greater than 1.0, these serpentine soils have ratios varying from 0.08 to 0.80. Also, nickel occurs at toxic levels on some, but not all, serpentine soils. Furthermore, they are almost always acutely deficient in nitrogen, phosphorus, potassium, and sulfur, and often are deficient in molybdenum.

Revegetation has succeeded after topsoiling with nonserpentinitic soil, but limited supplies of suitable topsoil near the site generally restrict widespread use. Nontopsoiled sites that are seeded and fertilized with nitrogen, phosphorus, and potassium may grow a sparse stand of plants for one to two years; after that, the fertility is depleted, and the seeded species may die out, leaving the slope bare.

Revegetation studies

We conducted studies on a serpentine soil (calcium-magnesium ratio of 0.24; phosphorus 5 ppm and potassium 40 ppm) in Lake County, northern California, near the McLaughlin Gold Mine operated by Homestake Mining Company. We planted 14 species of legumes and grasses under three fertilization treatments to determine which species would be more likely to persist in revegetation plantings.

Native grasses, from seed collected from local serpentine sites, were California melic, Torrey melic, squirreltail, and foothill stipa. We also included two weedy non-native species found growing on serpentine near the site: nitgrass and red brome. The rest of the plants were commercially available species frequently seeded in range improvement or revegetation projects throughout the state: rose clover, nungarin subclover, lana vetch, blando brome, zorro fescue, tall fescue, berber orchardgrass, and perlagrass (table 1).

We tested three fertility levels: (1) untreated control, (2) NPKS (100 pounds nitrogen per acre, 55 phosphorus, 98 potassium, and 135 sulfur), and (3) NPKSCa (100 pounds nitrogen per acre, 55 phosphorus, 98 potassium, 1,040 sulfur, and 1,070 calcium). The fertilizer treatments were the main plot factors and the species were subplots in a split-plot experimental design. Each treatment was replicated four times. Calcium was supplied as gypsum, nitrogen and phosphorus as ammonium phosphate, potassium as potassium sulfate, and sulfur as gypsum, potassium sulfate, or ammonium sulfate.

The grasses blando brome, red brome, and perlagrass had significantly greater seedling numbers in the NPKSCa treatment (table 1). Complete fertilization at planting time thus may be important for successful establishment of these species on serpentine soils and, by speeding stand establishment, may improve the ability of the plants to control erosion.

Fertilization greatly affected the survival of a species. Lana vetch, an annual legume, showed good survival but poor vigor in the untreated control. All other species including the serpentine-adapted grasses, had better survival in the two fertilizer treatments than in the control. Zorro fescue was the only species that had significantly greater survival in the NPKSCa treatment, indicating that it has little ability to survive on serpentine soil without correction of the calcium/magne-

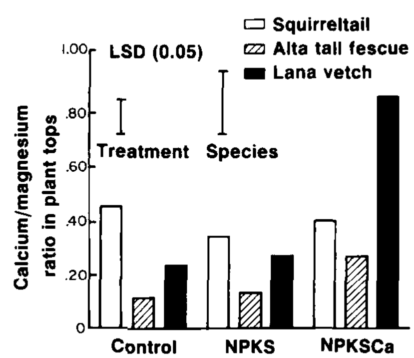

Fig. 1. Squirreltail, a native grass, had the most favorable calcium-to-magnesium ratio at the end of the season in untreated plots and was the best prospect for long-term survival on serpentine soils.

TABLE 1. Establishment, survival, and biomass production of 14 species planted on a disturbed serpentine soil

Species	Number of seedlings after one month			Survival after one complete growing season			Total above-ground biomass		
	Control	NPKS	NPKSCa	Control	NPKS	NPKSCa	Control	NPKS	NPKSCa
	number of plants per 100 seeds planted			*percent of viable seed planted*			*lb/acre dry wt.*		
Legumes									
Rose clover (*Trifolium hirtum*)	5	22	22	0	39	30	0	178	232
Nungarin subclover (*Trifolium subterraneum* 'Nungarin')	36	43	44	7	40	28	<9	258	178
Lana vetch (*Vicia dasycarpa*)	36	45	44	26	40	35	80	1790	3120
	LSD*:treatment NS, species 32			LSD:treatment 27, species 22			LSD:treatment 1737, species 1160		
Annual grasses									
Nitgrass (*Gastridium ventricosum*)	1	7	12	1	13	22	>9	18	355
Zorro fescue (*Vulpia myuros* var. *hirsuta* 'Zorro')	16	24	30	1	6	37	<9	80	355
Red brome (*Bromus rubens*)	22	27	57	2	26	46	<9	160	544
Blando brome (*Bromus mollis*)	33	22	51	2	27	46	<9	107	446
	LSD:treatment 25, species 23			LSD:treatment 24, species 20			LSD:treatment 285, species 223		
Perennial grasses									
Berber orchardgrass (*Dactylis glomerata* 'Berber')	2	4	9	0	0	0	0	53	27
Alta tall fescue (*Festuca arundinacea* 'Alta')	22	13	26	4	10	8	27	258	205
Perlagrass (*Phalaris tuberosa* var. *hirtiglumis*)	24	41	46	0	12	11	0	178	178
California melic (*Melica californica*)	15	20	33	1	12	19	<9	80	98
Torrey melic (*M. torreyana*)	6	5	9	2	17	17	27	125	160
Squirreltail (*Elymus multisetus* [= *Sitanion jubatum*])	27	32	41	5	10	17	27	125	134
Foothill stipa (*Stipa lepida*)	32	26	27	2	7	10	<9	27	18
	LSD:treatment 19, species 18			LSD:treatment 11, species 10			LSD:treatment 12, species 11		

* All least significant differences (LSD) are at the 5 percent probability level.

sium imbalance. The native perennial grasses, as a group, had an average survival of 10 percent after one growing season, which was significantly greater than the 5 percent of the non-native perennial grasses ($P<0.05$).

Lana vetch and all annual grasses produced more biomass in the NPKSCa than in the other treatments (table 1). The perennial grasses did not show this improvement. In another study (data not shown), however, where perennial grasses were transplanted from flats and gypsum was incorporated into the top 1½ inches of soil, biomass production was significantly higher in the NPKSCa treatment. This result indicates that perennial grasses do respond to an improvement in the calcium status of the soil, but that the fertilizer or amendment may need to be incorporated into the soil to be utilized optimally.

The non-native perennial grasses produced slightly more biomass than did the native perennials (102 versus 67 pounds per acre, respectively), but the difference may be attributed to rapid growth of nonnatives when the fertility of the site was high early in the season. Perlagrass, for instance, grew vigorously until early April, when it developed severe nitrogen deficiency symptoms and stopped growing. Neither perlagrass nor berber orchardgrass shows promise for long-term survival or serpentine soils. Alta tall fescue and the native perennial grasses grew vigorously until the end of the season and did not show obvious nutrient deficiencies.

Discussion

The results indicate that careful selection of plant species for revegetation projects on serpentine soils is crucial. Of the non-native perennial grasses tested in this study, Alta tall fescue would probably give the best results on serpentine sites with adequate soil depth. Of the native perennial grasses, squirreltail offers the best prospect for long-term survival, because it has physiological mechanisms to maintain favorable calcium/magnesium ratios in its tissue on an unamended soil (fig. 1). The non-native annual and perennial species maintain improved calcium/magnesium ratios in their tissue when calcium is added to the soil (ratios are typically greater than 1.0 in plants growing on nonserpentine soils).

Squirreltail grows too slowly to control erosion in the short term, but it may provide long-term cover on serpentine slopes. Unfortunately, seed of this species is not commercially available.

Two commercially available perennial grass species, not tested in this study, are occasionally seen growing on serpentine sites: Topar pubescent wheatgrass (*Agropyron trichophorum*) and smilo (*Oryzopsis miliacea*). These species show some tolerance to serpentine soils and could be useful in revegetation.

Conclusions

Blando brome, red brome, and lana vetch can provide a rapid ground cover on serpentine soil to reduce erosion if fertilized with adequate nitrogen, phosphorus, potassium, sulfur, and calcium. These species may die out if fertility is not maintained over subsequent years. Long-term cover can be provided, however, by the perennial grass species that are tolerant of serpentine soils and that can be successfully established.

Richard F. Smith is Farm Advisor Intern, University of California Cooperative Extension, San Diego County, and Burgess L. Kay is Specialist, Department of Agronomy and Range Science, UC Davis.
This study was made possible by a grant from the Homestake Mining Company.