SOILS-Management
CP366-100-3/83 Rev
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rev-100-9/83jmp

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LEGUMES FOR EROSION CONTROL IN SOUTHERN CALIFORNIA[1]

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ABSTRACT--The energy crisis of 1973 has led to increased cost of artificial N fertilizer and a renewed interest in the use of legumes as a biological nitrogen source for environmental plant materials. Hykon and Kondinin rose clover, when properly inoculated and fertilized with phosphate and sulfur, have proven a reliable first year erosion cover on disturbed soils under non-irrigation and have reseeded themselves adequately through seven growing seasons. Recent trials with early maturing subclovers indicate that this species may also have application for erosion control under non-irrigation. Under irrigation, preliminary results indicate that strawberry clover varieties have demonstrated good establishment vigor for erosion control and ground cover. All of these clovers fix ample quantities of nitrogen and improve soil nitrogen and organic matter levels. Establishment and management of these clovers are discussed.

1/ Paper presented at the International Erosion Control Association Conference XIV, Hanalei Hotel, San Diego, CA, February 24-25, 1983.

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INTRODUCTION

The soils of San Diego County, as well as many other parts of southern California, are low in fertility. Nitrogen is the most limiting factor for plant growth on these soils and often they are also deficient in phosphorus and sulfur (McKell et al., 1970; Murphy et al., 1973). Also critical is the southern California climate with short winter moisture, long hot summer drought, and a high degree of yearly and monthly variability (Helphinstine et al., 1983). These combined factors often led to the "hit-and-miss" approach of erosion control practices of the 1950s and '60s when introduced annual grasses were the rule-of-thumb. During this period, seedings of roadsides and other non-irrigated critical areas in California depended primarily on annual ryegrass *(Lolium multiflorum* Lam*)*, plus massive applications of nitrogen fertilizers, to establish ground cover in minimum time at minimum cost. This has several disadvantages. Grasses gave highly variable first-year establishment results. High rates of fertilizer, in combination with ryegrass, result in a large amount of plant material--much in excess of what is necessary for erosion control--and excess fertilizer may be released into runoff water. The heavy mat of dry grass is a fire hazard in the summer and will restrict the reestablishment of itself and other desirable showy plants such as poppies, lupines of shrubs (Kay 1972). Annual ryegrass has also been shown to exhibit allelopathic properties toward native shrubs and other plants (Gartner et al., 1957; McKell et al., 1969).

The process used to produce nitrogen fertilizer from natural gas was improved after World War II, thus reducing the cost of inorganic nitrogen. Farmers turned from rotational farming and the use of legume crops to the growing of high value cash crops in short crop rotations which were highly dependent upon inorganic nitrogen fertilization (USDA, 1980; Auld et al., 1982).

Even though inexpensive nitrogen through the 1950s and 1960s--combined with cultural practices and varieties that maximize crop yields under high levels of nitrogen--helped to revolutionize modern agriculture (USDA,1980), the production of 1 kg of nitrogen in urea fertilizer requires the consumption of 20,000 kcal of natural gas and other non-renewable energy resources (Green, 1978). With the oil embargo of 1973, the energy crisis was upon us; and natural gas prices rose accordingly, causing anhydrous ammonia to increase 312 percent during the period from 1970 to 1980 (Douglas, 1980). Coupled with this several fold increase in nitrogen costs, we have become increasingly dependent upon ammonia imported from Russia and Mexico to supply our demand for inorganic nitrogen fertilizer (Auld et al., 1982).

Since grasses had given inconsistent results in San Diego County for erosion control on low fertility critical sites, we began a screening program in 1974 for legumes that were adapted to our conditions and were able to compete and grow adequately to provide erosion control and ground cover. In the last nine years, we have found varieties of rose *(Trifolium hirtum* All*)*, sub *(T. subterraneum* L.*)*, and strawberry *(T. fragiferum* L.*)* clovers to satisfy our criteria.

ROSE CLOVER

Early-maturing varieties of rose clover have been found useful in revegetating southern California roadside embankments and other critical areas to control erosion and improve soil (Graves et al., 1980). This annual legume, said to grow in soils where few other plants survive, is adapted to areas of San Diego County below 900 m (3000 feet). In its original habitat--the Mediterranean region of North Africa, Asia Minor and southern Europe--it grows in dry, sterile fields, on slopes and sandy steppes, and along roadsides.

[a] Each plot sampled by four squares (30x30 cm) in June 1978.

[b] Means followed by the same letter are not significantly different at the 5 percent level by Duncan's multiple range test.

Hykon proved to be, by far, our best variety for winter growth, total dry matter, and cover. Kondinin, the second-highest yielder, seems to be similar to Hykon in adaptability to San Diego County, but produces less cover.

Comparing rose clover with grasses, we used embankments in the proximity of the variety trial location. Hykon rose clover, due to its success, was compared to annual ryegrass. The seeding rates for Hykon and annual ryegrass were 22 and 25 kg/ha, respectively.

Visual estimates in the first growing season found both annual ryegrass and Hykon to be slow in covering the soil during the cool early part of the growing season (December-February). No real difference between them showed up until March, when moisture stress began to occur. During March and April, Hykon made maximum growth and attained more than 90 percent plant cover by the flowering period (in early April). Annual ryegrass, having a longer maturation season than Hykon, tapered off in early April as soil moisture was depleted, attaining only 40 percent cover by the end of the first growing season. Rainfall, apparently, was not adequate for annual ryegrass to mature and no seed was produced. Thus, by the third year, the clover plots had abundant seed and nitrogen, whereas the ryegrass plot had neither. Dry matter yield of Hykon and ryegrass were similar in the first growing season; but by the third season, the Hykon yield was almost six times that of the ryegrass. By then, the ryegrass samples were a mixture of volunteer red brome *(Bromus rubens)* and forbs, as well as barley from the straw and some ryegrass, whereas the Hykon sample was predominantly Hykon. Thus, the ryegrass planting was deteriorating while the Hykon stand was improving. After the sixth season, the Hykon rose clover continued to maintain itself on this embankment and provided much better slope protection than the annual ryegrass seeding (Table 2).

Table 2. First- and third-year Hykon rose clover and annual ryegrass production on south Escondido I-15 offramp

Variety	DRY MATTER YIELD 1st year	 3rd year	 6th year
Hykon rose clover	2000	6020	3685
Annual ryegrass	2420	1060	752

[a] Average of two 30-cm-square samples from each plot in first year (May 1977); and, two 1-meter-square samples from each plot in third (June 1979) and sixth (June 1982) years.

As for the grass, blando brome, plots of blando brome were seeded at 44 kg/ha and fertilized with 14-14-7 at 300 kg/ha on the north Escondido embankment, adjacent to the rose clover variety trial of 1977/78. During an above-average-rainfall year, the Hykon rose clover still outyielded this grass (5200 kg/ha, compared with 4710 kg/ha).

These early encouraging results with Hykon rose clover led the California Department of Transportation of District 11, in San Diego, to incorporate Hykon rose

[a] Sampled with 0.5 m square on June 15, 1982.

[b] Average of three (3) replications.

Although the above clover yields seem exceedingly high, one can atrribute part of this production to the above-average rainfall of 350 mm (14 inches) that fell during the growing season. Even so, these results seem quite promising in light of the relatively poor showing by the resident annuals on this site. The difference is even more spectacular when we compare the nitrogen levels of the foliage of the clovers (2.2 percent), versus the resident annuals (0.8 percent), measured on June 15.

These preliminary results indicate that early-maturing subclovers may have a role to play in erosion control under non-irrigation if they continue to establish and persist in drier-than-average-rainfall years.

STRAWBERRY CLOVER

A prime candidate for irrigated erosion control and ground cover in southern California is strawberry clover. While rose and subclovers show adaptation in San Diego's coastal, inland and foothills' climate zones under unirrigated conditions for winter and spring plant cover, they are not considered adapted to irrigated conditions where summer greenery is needed.

Strawberry clover has been around the agriculture scene many years, and it has been a recommended species to use in irrigated pastures mixes in the western states since the 1950s (Peterson et al., 1962; Hollowell, 1960; Raguse et al., 1967).

Hollowell (1960) describes this clover as: "... a perennial which spreads by means of creeping stems that root at the nodes. It is similar to white clover in appearance of leaves and stems and in habit of growth. Flower heads are mostly pink to white and usually are round; some may be slightly pointed. Their resemblance to strawberries give the clover its common name. As the seed matures, the seed envelope becomes inflated and looks like a tiny gray to light brown balloon. Seed color varies, but usually is reddish brown, or yellow, flecked with dark markings."

Of all the clovers, this clover is probably the most tolerant of high concentration of salts. It is also highly tolerant to flooding during cold weather. It is known to survive flooding, of up to 60 days and more in the winter (Peterson et al., 1962).

Strawberry clover has recently come upon the southern California landscape scene as "O'Conner's Legume" from Australia (Anonymous, 1982). O'Connor's is one of several strawberry clover varieties developed in Australia. Palestine and Sherman's are other noteworthy Australian strawberry clover varieties. Salina is a California selection from the Palestine variety (Peterson et al., 1962).

With both O'Connor's and Salina varieties available to the landscape industry, we embarked upon an evaluation program to determine any differences in their growth and adaptation characteristics and the value of these strains for irrigated ground covers.

On the University of California-San Diego campus, a series of replicated plots were seeded--in early April 1982--to O'Connor's, Salina, two tall fescues (Rebel and Chemfine) and two crown vetches (Penngift and Emerald). Using a 50 kg/ha seeding established. Much of the early pioneer work on pellet inoculation in California was reported by Holland and Associates (1969). At that time, the most effective inoculation process was a two-step process called "lime pelleting," which consisted of sticking rhizobial inoculum to the seed with a gum-Arabic glue and drying the wetted seed with a finely pulverized limestone that separated and coated the seed.

In spite of this improved inoculation technique, native ineffective California rhizobia presented a barrier to rose, sub and strawberry clover rhizobia sufficiency. During the 1970s, rhizobia strains for rose and sub clover were screened for efficiency and ability to compete with the California native ineffectives. Superior competitive rhizobia strains were developed for sub and rose clovers by Jones and his associates (1978). It was also found that high rhizobial inoculum rates increased field growth proportionally, thus a new pellet inoculation technique was developed which provided large numbers of viable effective rhizobia coated to the seed. Street (1975) showed the superiority of another new inoculation technique Pelinoc-Pelgel®, over the old "lime pelleting" method (Table 5).

Table 5. Effect of inoculation methods on subclover foliage yields.

		Subclover Yields kg/ha[b]		Increase Over Lime Pelleting
		Lime-Pelleting[a]	Pelinoc-Pelgel®	%
Hopland Field Station,	Vassar	4114	6446	57
	Middle	2112	4169	97
	Orchard	616	1342	118
Johnson Ranch, second year		1650	2970	80
Daley Ranch		1806	2577	43

[a] Per method described in Holland et al., 1969.

[b] Provided by Street (1975).

The Pelinoc® system is designed to supply 25,000 to 50,000 viable bacteria per clover seed. It is a do-it-yourself system designed to be used on the farm, or on the erosion control site. Other materials and methods, including custom inoculation, are on the market.

Strawberry clover has been found to be quite rhizobial strain specific and is not effectively inoculated by the same strains that inoculate sub and rose clover. It can also be subjected to the same problems associated with the native California rhizobia ineffectives that has plagued sub and rose clovers (J.C. Burton, personal communication). Dr. Joe Burton of NifTAL has selected several highly effective rhizobial strains for this species and they are commercially available; but, research is continuing on finding highly competitive strains for use in California where native ineffectives are present.

The key to the decision whether to pellet inoculate or not is whether you believe in insurance. One must remember that the cost of pellet inoculation is usually nodulation and eventual nitrogen fixation (Chambers et al., 1980). Added fertilizer nitrogen can also encourage weed invasion and competition with the clover.

Seeding

The following table gives the approximate range of seed per kilo for the sub, rose, and strawberry clover:

Clover Species	Number of Seeds per Kilo
Sub	132,000 to 187,000
Rose	300,000 to 363,000
Strawberry	638,000 to 849,000

We have obtained good first year stands of rose clover with as little as 22 kg/ha of pellet-inoculated seeds. If seeded in the right season, pellet inoculated, fertilized properly and straw mulched to cover the seeds, the following range of seeding rates would work:

Clover Species	Seeding Rate (kg/ha)
Sub	40 - 60
Rose	25 - 40
Strawberry	15 - 25

The California Department of Transportation is often forced to go to higher seeding rates than this due to the frequent out-of-season erosion control seedings that occur. Since highway embankment slopes are required by law to have their erosion control applied upon project completion, it is difficult to coordinate all project completions to coincide with the best seeding season. Seeding rates are increased to compensate for the less than desirable seeding period conditions.

Ideally, we should schedule the seeding in the fall to coincide with the beginning of the rainy season for the sub and rose clover. For strawberry clover, either early fall or late winter is possible, since its establishment and persistence is assisted by adequate irrigation.

Important Point: All applications of pellet-inoculated clovers should be dry spread. Inconsistent establishment results have occurred when pellet-inoculated seed were applied by hydraulic means (hydroseeding). Running the coated seed through water slurries cause the rhizobia bacteria to be washed off the seed and take away the advantage that the pellet inoculation can provide the clover for its proper establishment. An additional factor of equal consideration against the pellet-coated, clover-water-slurry application is the addition of fertilizers to the hydraulic operation. Fertilizers of the phosphate type acidify the water slurry to the degree that most of the root-nodule bacteria are killed within a few minutes of contact with the acid fertilizer (Brown et al., 1982).

SUMMARY

Increasing nitrogen fertilizer costs and high fossil fuel energy demands for nitrogen fertilizer manufacturing has encouraged us to take a second look at legumes--which obtain their nitrogen from the atmosphere--as erosion control and groundcover plants. Grasses have played a major part in this role, but they demand

Brown, M.B., D. Dolf, R.D. Morse and J.L. Neal. 1982. Survival of rhizobium inoculum in hydroseeding slurries. Proceedings of Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, University of Kentucky, Lexington, pp. 681-685.

Chambers, C.A., S.E. Smith and F.A. Smith. 1980. Effects of ammonium and nitrate ions on Mycorrhizal infection, nodulation and growth of Trifolium subterraneum. New Phytol. 85:47-62.

Donald, C.M. 1970. Temperate pasture species. In "Australian grasslands." Ed. R.M. Moore, pp. 303-320, Australian National University Press:Canberra.

Douglas, J. 1980. U.S. Nitrogen industries at the crossroads. Proc. Far-Western Fertilizer Conf. Spokane, Wash. 1980.

Gartner, F.R., A.M. Schultz and H.H. Biswell. 1957. Ryegrass and brush seedling competition for nitrogen on two soil types. J. of Range Mgmt. 10:213-220.

Gladstone, J.S. 1975. Legumes and Australian agriculture. J. of Australian Institute of Ag. Sci. 41:227-240.

Graves, Walter L. and James R. Breece. 1979. Legumes for orchard and vineyard cover crops. University of California Cooperative Extension, San Diego County Publication 326, 4 pp. mimeo.

________________, B.L. Kay and Tom Ham. 1980. Rose clover controls erosion in southern California. California Agric. 34(4):4-5.

Green, Maurice B. 1978. Eating oil: energy use in food production. Westview Press, Boulder, CO, 205 p.

Helphinstine, W.N., V.W. Brown and R.M. Love. 1983. Hard seed characteristics of rose clover. Calif. Agric. (in press).

Henson, P.R. 1963. Crown vetch--a soil conservation legume and a potential pasture and hay plant. USDA/ARS Publication 34-63, 9 pp.

Holland, A.A., J.F. Street and W.A. Williams. 1969. Range-legume inoculation and nitrogen fixation by root-nodule bacteria. UofC Exp. Sta. Bulletin 842, 19 pp.

Hollowell, E.A. 1960. Strawberry clover: a legume for the West. USDA Leaflet 464, U.S. Gov't Printing Office, Washington, D.C.

Johnson, W.H., W.A. Williams and W.E. Martin. 1956. Rose clover yield and quality. Calif. Agric. 10:7-8.

Jones, M.B., J.C. Burton and C.E. Vaughn. 1978. Role of inoculation in establishing subclover on California annual grasslands. Agron. J. 70:1081-1085.

Kay, B.L. 1972. Plants for roadside seedings in Sierra Nevada foothills. Agron. Progress Report No. 40, UofC Dept. of Agron. & Range Science, Davis: 4 pp. mimeo