Intensive management of small rangeland units increases forage and lamb productivity

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Fertilizer and seed treatment allow higher stocking rates

Large areas of California have long been used as grazing lands, because they lack irrigation or have infertile soils and terrain too steep for cultivation. With increasing frequency, these rangelands have been divided into smaller residential units for Californians who derive their primary income from nonagricultural sources. The purpose of this and the following report is to show that even small acreages of such marginal land can be used productively for raising livestock.

Part-time, small-scale livestock producers have some advantages over traditional ranchers. Most conventional ranchers must cover any mortgage costs on the land as a direct charge against animal production, while small landowners often pay interest charges on land debt from other income sources. As a result, small-scale producers usually can afford to invest capital in more management options than traditional ranchers. Also, owners of small properties can impose a higher level of physical management on their plants and animals.

Ranch enterprises of all sizes and economic scales, however, can benefit from intensive management of small rangeland units. Enterprises run by a full-time operator frequently are too large for intensive management of all the land, but increased management may be effective on a small portion of the ranch where high animal performance or high productivity per acre is desired. The small, often part-time, ranch enterprise may benefit from intensive management to increase productivity without acquiring additional land.

In this article, we show how seed and fertilizer inputs can significantly increase forage quantity and quality; the following report indicates that, when forage is adequate, intensive management of ewes and lambs can be cost-effective. The benefit of these practices is that animal production can be increased without buying or renting additional land.

Basic principles

Productivity of California's annual rangelands can be increased in many ways, but the technologies outlined in this report are based on two important principles: first, undesirable plants can be replaced with more productive and nutritious species and, second, total forage yield of both desirable and undesirable species often is limited by the availability of minerals in shallow rangeland soils. A first step toward improving forage production on an annual range site thus often involves seeding with a productive, nutritious legume plant such as subclover or rose clover. Then, to produce maximum benefits from the clover, one must supply adequate soil nutrients.

The fertilizer requirements of different rangeland soils vary. Although the elements nitrogen (N), phosphorus (P), and sulfur (S) generally promote total plant growth, often only phosphorus and sulfur fertilizers are applied. The nitrogen then is obtained from atmospheric nitrogen gas (N_2) through fixation by *Rhizobium* bacteria associated with clover roots. By seeding with clover, providing the proper *Rhizobium* bacteria, and fertilizing with phosphorus and sulfur, the landowner can thus introduce a highly nutritious forage plant to the system and obtain the equivalent of low-cost nitrogen fertilizer through nitrogen fixation.

Clover and *Rhizobium*

Typical results obtained at the University of California Hopland Field Station in Mendocino County in 1985 showed the benefits associated with clover seeding in an annual range system (table 1). In October 1984, all plots on the Sutherlin loam soil at the site were fertilized with phosphorus and sulfur before planting of 'Woogenellup' subclover (*Trifolium subterraneum* L.), 'Blando' bromegrass (*Bromus mollis* L.), or a 50:50 mixture of the two species. Clover seeds were inoculated with *Rhizobium* bacteria before planting.

The clover alone or in combination with the grass increased forage dry matter and total crude protein by more than 60 percent while maintaining an adequate protein concentration in the forage. Planting bromegrass into an existing grassland is seldom recommended, but it can improve forage yield significantly on land from which brush has recently been removed.

Rhizobium bacteria were a critical factor in obtaining the response reported in table 1. The importance and persistence of those microorganisms are evident in results of three years of field tests on a Laughlin loam soil at Hopland (fig. 1). In that study, 'Woogenellup' subclover seeds were planted with or without *Rhizobium* inoculation in October 1976. All plots were replanted with uninoculated seeds in October of the two subsequent years. (It's not necessary to replant subclover on sites where it grows in the first year, but in this experiment, there was little subclover growth in the uninoculated plots at any time, so tests for the presence of *Rhizobium* bacteria in the following years would not have been possible without providing new seeds.) When plots were harvested each spring, measurements showed that inoculating with *Rhizobium* bacteria only in 1976 was sufficient to increase forage dry weight and total crude protein by 80 to 300 percent during the next three years.

TABLE 1. Effect of seeding *Rhizobium*- inoculated subclover and bromegrass into a Sutherlin loam rangeland soil fertilized with phosphorus and sulfur

Seed planted	Forage dry matter	Forage crude protein: Total	Forage crude protein: Concentration
	- - - - *lb/ac* - - - -		%
None	3,520 a	392 a	11.1 a
Grass	3,860 a	408 a	10.6 a
Clover	5,840 b	660 b	11.3 a
Grass + clover	6,240 b	648 b	10.4 a

NOTE: Mean values followed by different letters in a single column are significantly different at $P \leq 0.05$.

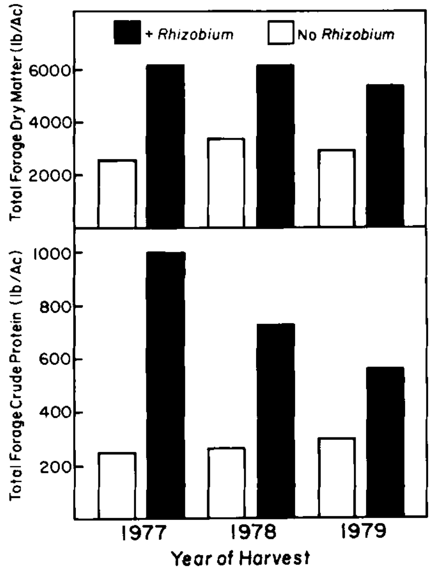

Fig. 1. *Rhizobium* inoculation of subclover seed significantly increased forage dry matter and crude protein for three years.

Effects of fertilizer

The effect of phosphorus and sulfur fertilization on forage production was demonstrated on three soils seeded with *Rhizobium*-inoculated subclover and bromegrass (table 2). We have reported data from 1980, but results were similar in 1981. On each soil type, fertilization with phosphorus and sulfur produced a highly significant increase in yield of forage dry matter and total crude protein. Using an isotope-dilution technique with a heavy isotope of nitrogen, we calculated that the phosphorus/sulfur fertilization treatment also increased the amount of nitrogen fixation. Providing adequate phosphorus and sulfur fertilizer and seeding with *Rhizobium*-inoculated clover thus resulted in a larger amount of free nitrogen fertilizer through fixation by the *Rhizobium*-clover symbiosis.

A crude measure of these benefits can be obtained by estimating lamb weight gains using a conversion factor of 0.108 pound of lamb per pound of forage. This factor was calculated from feeding experiments using forages of different qualities harvested from rangelands. Such theoretical calculations of animal weight gains must be treated with caution, but they are in general agreement with data reported from direct grazing studies in the following article.

Influence of grazing

A disadvantage of measuring forage production once in the spring, when there is a maximum amount of standing plant material, is that the plants seldom reach that stage in a grazed system. On the other hand, measuring only weight gains of animals grazing on plots with different fertilizer treatments provides no direct data on how the fertilizer affects plant growth. An intermediate approach, in which ungrazed plots were compared with hand-clipped plots, showed that harvesting plants, presumably either by clipping or by grazing, decreased total forage dry matter production much more than it decreased crude protein accumulation (table 3). In fact, the clipping actually increased crude protein concentration in the forage by 60 percent on the fertilized plots (24.8 versus 15.5 percent). These results reflect the important fact that new, young shoots regrowing on clipped or grazed plants contain a higher protein concentration than does older forage growth.

The data in table 3 came from additional plots included in the study reported in table 2. In this case, half of the plots planted in October 1979 were clipped on March 3 and again on April 21, 1980, while the other half were harvested only on the later date. Data for plots that had been planted with *Rhizobium*-inoculated subclover and bromegrass were averaged across three different soil types for each of the two fertilizer treatments.

The data in table 3 lead to two important conclusions: first, the fertilization and seeding treatment increases forage

TABLE 2. Fertilizer effects on forage production on three rangeland soils seeded with *Rhizobium*-inoculated subclover and bromegrass

Soil type	Fertilizer	Forage dry matter	Forage crude protein: Total	Forage crude protein: Concentration	Nitrogen from N_2fixation†	Projected lamb gain‡
		.... *lb/ac*		%	.... *lb/ac*	
Laughlin loam	None	2,900	380	13.1	14	313
Laughlin loam	P + S	7,490***	1,060***	14.2	61***	809***
Yorkville clay	None	2,790	408	14.6	23	301
Yorkville clay	P + S	4,210***	715***	17.0	56***	455***
Sutherlin loam	None	3,410	469	13.8	18	368
Sutherlin loam	P + S	6,110***	992***	16.2	54***	660***

NOTE: Mean values followed by *** show a fertilizer effect that is significant at $P < 0.001$.
† Nitrogen fixation was estimated by an isotope-dilution method.
‡ Potential weight gains of lambs estimated from previous feeding experiments.

The effect of *Rhizobium* on clover growth was evident five months after seeding. All plots received phosphorus and sulfur fertilizer. Only the plot with lush clover received an effective *Rhizobium* strain; the others received an ineffective strain or no *Rhizobium*.

TABLE 3. Fertilization and clipping effects on forage dry weight and crude protein

Treatment	Total forage		Crude protein concentration
	Dry weight	Crude protein	
	...... lb/ac		%
Unfertilized			
One harvest	3,030	419	13.8
Two harvests	1,900**	318	16.7
Fertilized with P + S			
One harvest	5,940 b	921 b	15.5
Two harvests	3,110*** b	771* b	24.8*** a

NOTES:
Values were averaged across the three range sites reported in table 2, and data from two clippings were summed for the two-harvest total.
Mean values followed by *, **, or *** show a harvest effect that is significant at $P \leq 0.05$, 0.01, or 0.001, respectively.
Mean values followed by the letters a or b show a fertilizer effect that is significant at $P \leq 0.05$ or 0.001, respectively.

production and thereby allows higher stocking rates and, second, it permits the plants to respond to grazing pressure by increasing the crude protein concentration in the young growing shoots. This two-fold response to fertilization allows more profitable production of lambs.

Conclusion

Planting clover seeds inoculated with *Rhizobium* bacteria and fertilizing with adequate phosphorus and sulfur can significantly increase forage production on numerous rangeland soils. The phosphorus and sulfur promote total plant growth, and the clover uses *Rhizobium* to fix nitrogen, a source of low-cost nitrogen fertilizer.

Specific recommendations for the species of clover and the amount of phosphorus and sulfur vary with climate and soil type. Information for each locality is available from UC Cooperative Extension farm advisors, but general recommendations for annual rangelands would be as follows: (1) Plant a minimum of 10 pounds per acre of subclover (*Trifolium subterraneum* L.), rose clover (*T. hirtum* L.), or both in areas that receive more than 10 inches of annual precipitation. Both clovers use a special *Rhizobium* inoculum, which is available commercially. (2) Fertilize at planting with 200 pounds per acre of 0-38-0-20, a mixture produced by combining treble superphosphate and elemental sulfur. The same fertilizer treatment normally will be required every other year to provide optimum phosphorus and sulfur, but with proper grazing management, the clover should persist indefinitely, and the *Rhizobium* will keep on fixing nitrogen.

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Fertilization increases profitability of lamb production on small pastures

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A grazing experiment conducted in conjunction with research reported in the previous article yielded encouraging economic results for phosphorus and sulfur fertilization and suggested that small-scale pasture management may be profitable for sheep producers. The goal of the experiment reported here was to determine the effect of phosphorus and sulfur fertilization on forage quality and on lamb weight gain.

Because of the costs, fertilizers are usually applied where nutrients produce large responses in productivity. Lamb production is particularly sensitive to nutrient intake and forage quality. Lambs are small-bodied ruminants with high nutrient requirements per unit of body weight relative to those of mature sheep. As body weight increases, the total metabolic requirement per animal also rises, but the increase per unit of body weight decreases. Since total metabolic requirement is a major factor determining how much an animal eats, total feed intake should increase, but intake per pound of body weight should decrease as the animal grows. Small and large ruminants have the same proportion of their body weights in rumen contents, but small ruminants, eating more per unit of body weight, have a faster turnover of rumen contents. Since the digestion of a given forage occurs at a constant rate, the amount of forage digested per unit of intake is proportional to the length of time the forage spends in the rumen.

One possible response to this constraint of digestive capacity is for small ruminants to eat more, but two factors limit the extent to which they can compensate in this way. First, ruminants control turnover by ruminating particles to smaller sizes that can be passed from the rumen. The rumination rate often limits