Fertility studies reveal plant & soil needs

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Proper fertilization is important in realizing the great potential from the annual grasslands of California. One of the first studies indicated that forage production on improved dry-land pasture fertilized with nitrogen and phosphorus increased ten-fold over untreated pastures during the winter months of feed shortage. In another study it was found that fertilized pastures yielded about 3 1/2 times as much meat and wool as unfertilized pastures over the growing season.

A lysimeter helps scientists determine loss of soil nutrients by leaching from different soil-plant combinations.

Nitrogen

Ewes with lambs were in better condition and lambs gained slightly faster during the early winter months on N-fertilized range than those on native pasture. By the end of May the average lamb weight was the same for both groups. These and other trials showed that fertilization with N produced striking changes in the botanical composition of the pastures. The growth of grasses was stimulated and resulted in competition that crowded out the legumes in the pasture, producing lower quality feed in late spring, summer, and fall.

Nitrogen application at different times of the year showed that the earlier N was applied, the greater the winter forage growth. Total forage, measured at the end of the growing season, was not affected by time of application unless the applications were made after February. Later studies indicated that pastures which are closely grazed during the winter may become extremely N-deficient in the spring even though N was applied the previous fall.

Winter temperatures averaging much below 50° F severely limited response to N fertilization. Daily mean temperatures below this limit are common in the Hopland area and other regions of California during December, January, and February. It is important to apply N before the first autumn rains when average temperatures are above 50° F. Lack of response in cold weather is mainly a simple restriction of plant growth, but N-fertilized grass often is less damaged by frost and appears to recover faster than N-deficient grass.

Nitrogen rate trials showed, in general, that maximum yields were produced by about 80 pounds of N per acre, but that yields can vary widely from year to year. In a year when rains came early, the increased production due to N was linear up to a rate of 160 pounds per acre. Nitrogen fertilization generally increases palatability of the grass during the growing season.

Fall fertilization generally increases the percentage of protein in annual grasses and broad-leaved forbs early in the growing season. However, an early-season increase in protein percentage is not particularly beneficial since there is adequate protein for animals in unfertilized pastures at that time of year. The primary benefit from nitrogen in the early part of the season is the increase in dry matter production.

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As the season advances the protein level often decreases more rapidly in plants fertilized at moderate rates of nitrogen than those not fertilized. As a result, fertilized plants are often lower in protein at the end of the growing season than are those left unfertilized.

A comparison of the production of subclover pasture with N-fertilized pasture showed that, during the winter, a good subclover pasture produced dry matter equivalent to pasture fertilized with 40 to 60 pounds of N. During a spring with less than normal rainfall, clover pasture production was equal to pasture fertilized with 80 pounds of N per acre, but during a wet spring the subclover pasture produced more than double the dry matter that came from a plot fertilized with 160 pounds of N per acre. It also was found that the protein levels remained adequate for sheep on the subclover pastures during the summer dry season, whereas N-fertilized pastures were well below minimum levels. Low forage quality is a severe problem on N-fertilized pastures during summer and fall.

It has been found that N should be applied in the ammoniacal form because nitrates leach out rapidly with heavy rains, leaving the pasture fertilized with NO_3-N as if no fertilizer had been applied. Where heavy N applications have been made, denitrification has been observed during winter months when heavy rains keep soils water-logged. Little denitrification was found where light or no application of N had been made. Research in this area is continuing.

Clover inoculation

Pellet-inoculated subclover seed planted at various autumn dates on a site where effective nodulation was known to be a problem produced healthy plants when a mean ambient air temperature in the 6 weeks following germination ranged from about 49° to 62° F. When the mean temperature for the following 6 weeks was about 45° F, poor clover stands were produced. The results indicate that sufficient viable inoculant can survive on dry soils when fall rains are late and that early planting under these conditions is more effective than later planting in cold, wet soil.

Later studies have indicated large differences between strains of *Rhizobium* and between varieties of subclover. For example, the subclover variety Woogenellup is quite sensitive to the strain of bacteria required for effective nitrogen fixation. Some strains of *Rhizobium* are able to survive into the second year much better than others, and this has a striking effect on the stand of clover maintained in the sward. Numerous inoculants have been screened, and the most effective rhizobial strains have been put into commercial inoculants available to the rancher. These new strains have made the establishment of new subclover stands much more successful.

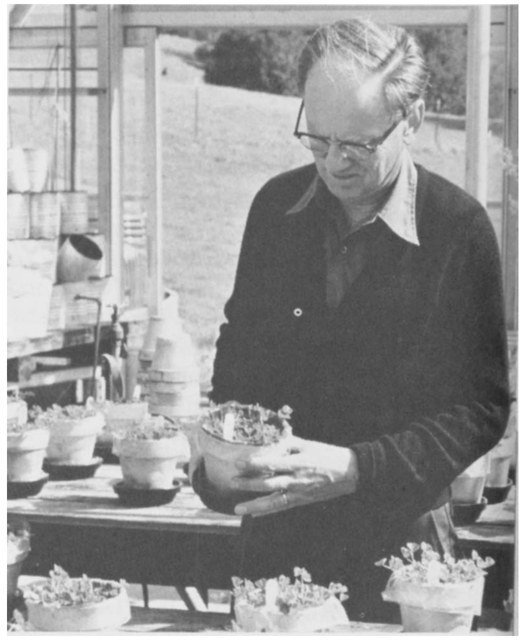
Phosphorus

The diagnosing of phosphorus status on various pastures has been undertaken from both the soil analysis and plant analysis standpoints. For example, it was found that the critical level of P could be as high as 0.7 percent in young subclover and as low as about 0.15 percent in flowering clover. Plant part utilized and frequency of plant defoliation also influenced the critical P values. With these variables influencing P concentrations, their use in assessing the P status of subclover under field conditions is limited, especially under pasture conditions where animals continually defoliate the plants.

The bicarbonate method of extracting soil phosphorus has been tested to determine the status of grassland soils, and 10 parts per million is considered to be the critical value. Phosphorus rate trials on a number of soils have indicated a wide range in the P requirements for maximum growth. Initial application of as much as 100 pounds of P per acre is required in some instances. Fertilizer P has a long residual value in soils. Some experiments have been observed for up to 16 years, and residual value of P is still measured. However, reapplication does have beneficial effects in these instances, so research is being continued to determine how often to reapply and what criteria should be used in deciding how much P to reapply.

Changes in botanical composition have an important influence on the protein level in the forage. Applying P increases the level of clover in the pasture and also increases the level of protein in the grass.

A study of the *in vitro* digestibility of subclover grown on extremely P-deficient soils showed that when P concentration in the clover went below 0.1 percent, digestibility decreased. Extremely low levels of P in the plant resulted in a reduced level of soluble carbohydrates, which were directly correlated with digestibility. It appears that on many of our ranges at the Hopland Field Station, low P could well limit the soluble carbohydrate level and digestibility of the forage plants growing in these poor soils.



Fertilizer responses of clover on various range soils are studied to determine the best management practices for improved rangelands.

Serpentine soil fertility

Annual grassland species have been successfully established on serpentine soils cleared of brush, and much of the soil fertility work for these soils, encompassing about 300,000 acres in California, was done at the Hopland Field Station. The annual grasses and clovers must be covered with 1/8 to 1/4 inch of soil, and clover seeds must be inoculated with an effective nitrogen-fixing *Rhizobium* because there appears to be no such bacteria in native serpentine soils.

Sulfur

Critical sulfur and sulfate sulfur concentrations have been determined for different plant parts of subclover and bur clover under greenhouse and field conditions. Rose clover and native clovers also have been analyzed in some of these studies. Age of the plant is important, and plant part must be considered if total S in the plant is the criterion for judging S status. If SO_4-S is used as the diagnostic criterion, differences between plant parts are not so great. Thus, whole plant tops are satisfactory for SO_4-S determinations but not for total S.

Extractions of S from the soil by a number of methods have indicated a very poor correlation between indicated amounts of S and plant growth response to S. Therefore, soil testing to determine S status is not recommended.

Elemental S has been compared with sulfate S as a source of S under the conditions at the Hopland Field Station as well as other areas of California. Finely divided elemental S appears to have a definite advantage over sulfate S since it produces higher yields over a longer period than yields produced by more soluble sources. A lysimeter study showed that nearly all the sulfate S applied in October was leached from the soil by December in a year when the first rains came November 7 and continued in heavy amounts. Temperatures were so cool that plants did not grow and they were unable to absorb sulfate S from the soil. In other years, when rains were more moderate and better distributed, losses of sulfate S were not so striking.

Elemental S must be oxidized to sulfate before it is available for plant growth. The sulfur oxidation rate in soil depends on favorable temperature, adequate moisture for metabolic activity of the bacteria, and surface area of the sulfur. Larger particles have less surface area and slower transformation to sulfate sulfur. When environmental conditions were satisfactory, sulfur particles less than 0.1 mm produced yield responses the first year equal to gypsum-sulfur (sulfate sulfur), but in the second year most of the gypsum-sulfur had been lost, while the elemental S continued to supply adequate levels of available S. A mixture of S particle sizes is sometimes desirable, with the fine particles becoming available soon and the larger particle sizes supplying S for several years. Elemental S mixed with triple superphosphate or with bentonite to form a prill that breaks down when wetted has been satisfactory from the agronomic point of view in the Hopland region.

About 40 pounds of sulfur per acre gave maximum yields; higher levels of sulfur generally increased the percentage of clovers in the pasture, improving quality of the forage without giving additional dry matter yields. To be competitive, subclover apparently requires higher levels of available S than do some of the grass species. Adequate grazing of any pasture or plot fertilized with phosphorus and sulfur is necessary to maintain a balance of clover and grass. The quality of the forage is affected by chemical composition as well as by the botanical composition. Research indicates that protein, soluble carbohydrates, and digestibility increase with increasing levels of sulfur where sulfur is deficient.

Phosphorus must be applied to serpentine soils for satisfactory growth of planted species. Benefits will also be seen from applying some nitrogen the first year, but it is not recommended because of high costs and leaching losses. Sulfur, molybdenum, and potassium also may be low. Calcium varies from extremely deficient to adequate. Single superphosphate is probably the most satisfactory fertilizer because it contains 20 percent phosphate, 12 percent sulfur, and 15 percent calcium. About 500 pounds of this fertilizer will meet the phosphorus requirements. It also meets the sulfur requirements and, in some instances, the calcium needs. However, there are many areas where additional calcium should be applied.

Molybdenum

Research shows that molybdenum deficiency is widespread, perhaps to the degree that about 25 percent of the soils are deficient in Mo after they are supplied with P and S. It was found that an application of 4 ounces of Mo per acre lasts at least 6 years in the field. By applying adequate levels of S with Mo, the concentration of Mo in the plant was maintained at about 1 ppm, but Mo applied without S gave rise to concentrations up to 8 ppm. This approached a level that may be toxic to animals under some conditions.

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