The Nutrient Status of Four Mountain Rangeland Soils in Western Nevada and Eastern California

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Artificial revegetation of depleted grazing lands on the eastern slope of the Sierra Nevada Range has resulted in varying degrees of success. Fair to good stands have been attained at elevations of 6,000-7,000 feet. At elevations of 8,000-10,000 feet the use of selected species and approved planting methods have resulted in good seed germination and emergence; however, seedlings lacked vigor and grew slowly. Three-year-old plants often appeared to be seedlings and produced herbage of less than 100 pounds per acre. The purpose of the study reported here was to investigate the nutrient status of the soil, one of the environmental factors which may have been responsible for the limited plant growth observed.

Review of Literature

The various methods of determining the nutrient status of the soil can be divided into two main classes: chemical and biological. The latter can be sub-divided into two groups: those in which certain microorganisms are used as the test plants and those in which higher plants serve as the nutrient-extracting agent. (Vandecaveye, 1948).

According to Vandecaveye (1948), some of the first pot-culture tests were conducted by Boussingault in 1838. Also, according to Vandecaveye (1948), Mitscherlich, in 1930, placed this type of investigation on a quantitative basis and studied the effect of a single factor on the growth of plants. Jenny et al. (1950) described the lettuce-pot culture in which Romaine lettuce was the indicator plant and the concept of relative yield was used to compare treatment response. Stephenson and Schuster (1941) developed a pot-culture technique in which sunflower was used as the indicator plant. The principle of this method consists of vigorous extraction of nutrients by massive plant growth on a small quantity of soil. Colwell (1943) used sunflower for determining boron-deficiency symptoms. Billings (1950) determined the nutrient status of soil developed from chemically altered rocks in western Nevada. Indicator plants were corn, sagebrush, and tobacco.

Vlamis et al. (1954) presented a greenhouse assay of the nutrient status of brushland soils in southern California. A modified Mitscherlich pot-testing technique was used and lettuce was the test plant. The authors reported that in general, the greenhouse evaluation of fertility correlated fairly well with field estimation of the natural vegetative cover. Mondrzak-Rosenberg (1958), using the method of Jenny et al. (1959), published the results of pot-fertility trials on Israel soils.

In recent years, some of the techniques used in pot-fertility work were examined critically. Armiger et al. (1958) evaluated the efficiency of different-size containers used in greenhouse
Table 1. Description of study sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Annual Precipitation (inches)</th>
<th>Native vegetation (Reseedings in the timber type were in the brushy or barren openings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smith Valley</td>
<td>4,750</td>
<td>5-6 tons of hay per year, Artemisia tridentata (cropped since 1960)</td>
</tr>
<tr>
<td>Dog Valley</td>
<td>6,300</td>
<td>Pinus jeffreyi, Ceanothus velutinus, Arctostaphylos patula, Artemisia tridentata</td>
</tr>
<tr>
<td>Sweetwater Flat</td>
<td>7,200</td>
<td>Arietisn tridentata, Chrysothamnus viscidiflorus, Prunus andersonii</td>
</tr>
<tr>
<td>Border Ruffian</td>
<td>8,200</td>
<td>Poor, Pinus contorta, Abies concolor, Artemisia tridentata</td>
</tr>
<tr>
<td>Galena Creek</td>
<td>9,700</td>
<td>Poor, Chrysothamnus spp., Lupinus spp., Pinus albicaulis, Pinus contorta</td>
</tr>
</tbody>
</table>

*Estimated precipitation

fertility studies. Alfalfa and millet were the test plants. These workers concluded that for alfalfa and probably for a number of other plants, greenhouse fertility trials could be conducted in 1- to 3-gallon containers as accurately as in larger ones. Terman (1959) made a statistical study of 141 greenhouse pot tests. Corn, oats, wheat, red clover, millet, ryegrass, and sudangrass were the test plants. Coefficients of variations were found to decrease with increase in yield. Three replications were found to be sufficient from the standpoint of accuracy. Statistical relationships were similar whether 2-gallon pots or No. 10 cans were used.

Methods and Materials

Soil from each of four mountain sites was selected for study. Artificial revegetation had been attempted at each. In addition, one productive cultivated soil was included in the study as a basis for comparison. The five sites are described in Table 1.

Various chemical characteristics of the soils are given in Table 2. The pH of a saturated paste was obtained by a glass-electrode meter (method 21b of the U. S. Salinity Laboratory) (1954). Electrical conductivity of a saturation extract was used to appraise the soluble-salt content of the soils (methods 3a and 4b.) The organic-matter content of the soil was determined by the Walkley-Black method, total nitrogen by the Kjeldahl method, cation-exchange capacity by the ammonium acetate method, total-extractable calcium and potassium by the flame photometer method, and phosphorus by the sodium bicarbonate method, all as outlined by the Oregon State College Soil Testing Laboratory (1954). Aluminum was evaluated by the LaMotte method (1952).

The pot fertility procedures used were adapted from those described by Jenny et al. (1950).

A sample of the surface 6 inches of soil was passed through a ½-inch mesh screen and 1600 grams of air-dry soil placed in 6-inch clay pots. These pots had been coated inside and outside with two layers of clear plastic.

The ten treatments included in this experiment were replicated three times in a randomized-block design. The various treatment combinations are presented in Table 3.

Lime was added as hydroxide of lime; manure was processed steer manure. Nitrogen was added as ammonium nitrate, P₂O₅ as calcium dihydrogen phosphate, and K₂O as potassium sulfate.

Lime, manure, and sulfur were mixed with dry soil. All other chemicals or mixture of chemicals were dissolved in water and the aqueous solution was mixed with the dry soil.

On May 14, 1956, five pre-soaked, sprouting Frontier barley seeds were transplanted to one series of pots and one Romaine lettuce plant was transplanted to a second series of pots. Pots were weighed daily and sufficient water added to bring the soil to approximate field capacity. Any excess water was caught and used in the following irrigation of the respective pots. All pots were sprayed with malathion every 5-7 days for mite and aphid control. Each

Figure 1. Barley growing on Dog Valley soil. Note response to nitrogen but no response to phosphorus.
Table 2. Chemical characteristics of the soils studied

<table>
<thead>
<tr>
<th>Study sites</th>
<th>pH</th>
<th>ECx10^3</th>
<th>Total organic matter (%)</th>
<th>Ca</th>
<th>K</th>
<th>Total exchangeable calcium and potassium (Meq/100gm)</th>
<th>Available phosphorus (ppm)</th>
<th>Aluminum</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smith Valley</td>
<td>7.0</td>
<td>1.3</td>
<td>0.08</td>
<td>1.06</td>
<td>22.17</td>
<td>13.50</td>
<td>1.98</td>
<td>26</td>
<td>Low</td>
</tr>
<tr>
<td>Dog Valley</td>
<td>5.9</td>
<td>0.2</td>
<td>0.06</td>
<td>2.79</td>
<td>13.74</td>
<td>6.04</td>
<td>0.79</td>
<td>44</td>
<td>High Upland Lithosol</td>
</tr>
<tr>
<td>Sweetwater Flat</td>
<td>6.4</td>
<td>0.5</td>
<td>0.13</td>
<td>1.76</td>
<td>14.90</td>
<td>3.63</td>
<td>0.79</td>
<td>25</td>
<td>Low Brown</td>
</tr>
<tr>
<td>Border Ruffian</td>
<td>4.6</td>
<td>3.6</td>
<td>0.11</td>
<td>3.40</td>
<td>11.88</td>
<td>0.88</td>
<td>0.16</td>
<td>52</td>
<td>High Minimal Chestnut</td>
</tr>
<tr>
<td>Galena Creek</td>
<td>5.0</td>
<td>0.2</td>
<td>0.11</td>
<td>3.40</td>
<td>11.88</td>
<td>0.88</td>
<td>0.16</td>
<td>20</td>
<td>Very High Mountain Alluvium</td>
</tr>
</tbody>
</table>

Replication was rotated weekly within the coldframe. Plants from all treatments were harvested 63 days after planting and the oven-dry yields determined.

**Results and Discussion**

The oven-dry yields of barley and lettuce produced by each fertilizer and/or amendment treatment on each soil are presented in Table 4.

Species, fertility, soil, species x fertility, species x soil, fertility x soil, and species x fertility x soil were all significant sources of variation at the 1-percent level of probability.

Duncan's Multiple Range Test (Duncan, 1955) at the 1-percent level of probability was used to compare the treatment main effects and interactions. The yield of barley over all fertility treatments and all soils was 33 percent greater than the yield of lettuce. Individual additions of manure, micronutrients (Mn), PK, or lime (L) did not increase yield above the check. Significant yield increases were obtained only from the following treatments as ranked: NK < NPK = NP < NPK + L = NPK + Mn. Soils differed significantly in mean yields and ranked as follows: Galena Creek < Sweetwater Flat < Border Ruffian < Smith Valley = Dog Valley.

Barley responded to addition of nitrogen on all soils except Galena Creek. On the 3 most acid soils, Galena Creek, Dog Valley and Border Ruffian, lime, in addition to nitrogen, was necessary for maximum barley response. This response was especially noticeable on the Galena Creek soil. Barley did not respond to phosphorus application on any soil (Figure 1). Neither species responded to addition of potassium.

Lettuce responded to addition of nitrogen on the Sweetwater Flat and Border Ruffian soils and to addition of nitrogen plus phosphorus on the Smith Valley and Dog Valley soils. The yield of lettuce did not increase significantly on the Smith Valley soil when either nitrogen or phosphorus was omitted from the fertilizer mixture. When both were applied, lettuce yield was about doubled. On the Dog Valley soil a significant response was obtained from nitrogen; however, addition of phosphorus was necessary for maximum response (Figure 2). On the Border Ruffian soil, lime, in addition to nitrogen, was required for maximum lettuce response. The response to lime appears to be the direct or indirect chemical effect of the calcium ion, since the response noted was on soils with a low pH and with small amounts of exchangeable calcium compared to the total exchange capacity (Table 2). Lime was not required for maximum lettuce response on the Smith Valley, Dog Valley, or Sweetwater Flat Soil. The poor lettuce response to fertilizers and/or soil amendments on the Galena Creek soil may be due to the very high level of soluble aluminum in this soil (Table 2). Bear (1957) reported that lettuce is especially sensitive to this element. On the Galena Creek soil the response of lettuce to fertilization apparently is suppressed by an aluminum toxicity.

Table 3. Treatments and rate of materials used

<table>
<thead>
<tr>
<th>Treatment and rate per acre *</th>
<th>Micronutrient mixture</th>
<th>Chemical</th>
<th>Pounds per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoP_2K_0 (Check)</td>
<td></td>
<td>Sodium borate</td>
<td>20</td>
</tr>
<tr>
<td>Lime—2 tons</td>
<td></td>
<td>Cupric sulfate</td>
<td>50</td>
</tr>
<tr>
<td>Manure—2 tons</td>
<td></td>
<td>Ferrous sulfate</td>
<td>50</td>
</tr>
<tr>
<td>NoP_2K_1</td>
<td></td>
<td>Magnesium sulfate</td>
<td>50</td>
</tr>
<tr>
<td>NoP_2K_0</td>
<td></td>
<td>Manganous sulfate</td>
<td>50</td>
</tr>
<tr>
<td>NoP_2K_1</td>
<td></td>
<td>Wettable sulfur</td>
<td>100</td>
</tr>
<tr>
<td>NoP_2K_1 + 2 tons lime</td>
<td></td>
<td>Zinc sulfate</td>
<td>50</td>
</tr>
<tr>
<td>NoP_2K_1 + 2 tons lime + micronutrients</td>
<td></td>
<td>Ammonium molybdate</td>
<td>1</td>
</tr>
</tbody>
</table>

*Subscripts indicate the number of 100-pound units per acre of fertilizer added
Data of these kind reveal specific information about the nutrient status of the soils studied. Low soil fertility and a high level of soluble aluminum appear to be the primary cause of poor reseeding response at the Galena Creek site. Low pH, excessive leaching of nutrients, and considerable erosion are factors contributing to the low fertility and aluminum problems. The Border Ruffian soil is deficient in both nitrogen and lime. These deficiencies, as measured by the pot-fertility technique, do not appear severe enough to account for the poor revegetation response observed. This poor response may be due to an aluminum toxicity (Table 2) or to one of the many environmental factors not evaluated. The Sweetwater Flat, Dog Valley, and Smith Valley soils are deficient in nitrogen; nitrogen, phosphorus, and lime; and nitrogen and phosphorus, respectively. On all sites, fertilizer and/or soil amendments will enhance the soil environment to the point where increased production can be expected if the other environmental factors of the site are favorable. Of course, final evaluation of fertilizer response will have to be made under field conditions and with a particular seeded or native species.

In addition to elucidating some of the nutrient deficiencies of the test soils, this study also served to point out some of the problems encountered in using test plants to indicate nutrient deficiencies in soil. The data indicate the two species used reacted differently to different fertility treatments on different soils. Since neither barley nor lettuce is grown on the range, the problem is to decide which species, if any one, best evaluates the nutrient status of a particular soil with respect to successful establishment and production of perennial seeded species. Perhaps a specific perennial plant should be used to evaluate the nutrient status of a specific soil where the perennial is now growing or is to be seeded.

The total environment cannot be evaluated from pot studies in the greenhouse or coldframe for several reasons. Moisture and temperature conditions are maintained near optimum in pot-culture studies. These conditions are not prevalent under range conditions. Soil samples are usually confined to the A horizons and thus give no indications of fertility conditions in the subsoil horizons. Soil is passed through screens to remove stones and debris. Such alteration of soil structure influences moisture-holding capacity and aeration.

In spite of these disadvantages,
the pot-culture technique does have promise for providing a rapid evaluation of soil nutrient deficiencies and of excesses of toxic elements. This is especially true in areas of diversified range soils where little or no soils work has been done.

Summary

Frontier barley and Romaine lettuce were used as indicator plants to evaluate the fertility status of four mountain soils and one cultivated soil by the pot-fertility technique. The study was conducted in a coldframe. Nine fertility treatments were used: lime, manure, micronutrients, NPK, NPK, NPK, NPK, NPK, NPK, + lime, and NPK + lime + micronutrients. A check treatment was also included. In general, the soils tested were deficient in nitrogen, phosphorus, and lime. Increased forage production can be expected if the deficient nutrients are supplied and if other environmental factors of the site are favorable. The indicator species used responded differently to different fertility treatments on different soils. This variation in species response together with environmental differences between coldframe and field conditions, makes it difficult to generalize the results obtained. In spite of these disadvantages, the pot-culture technique does have promise for providing a rapid evaluation of soil deficiencies and toxic excesses.

Literature Cited

LA MOTTE CHEMICAL COMPANY. 1952. La Motte Soil Handbook. La Motte Chemical Products Company, Baltimore 4, Maryland.

Responses of Annual Range to Urea Applied at Various Dates

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A number of field trials throughout the annual range type in California reported by Martin, et al. (1957), have indicated a marked response to nitrogenous fertilizers. The majority of these tests have produced economical livestock gains. Other workers (Love and Williams, 1956) (Hoglund, et al, 1952) have pointed out that nitrogen fertilization advanced the date of grazing readiness, increased total production and reduced annual fluctuation in forage yield by reducing drought and frost damage.

In all the work cited above the fertilizer was applied in the fall and in the ammonium form. Application of nitrogen was made before the first fall rains in order that it might be readily available to increase early growth rate of the young plants, and was applied in the ammonia form to reduce leaching. Tyler, et al. (1959) pointed out that the efficiency of fall application of ammonia depends upon the rate of nitrification, which is dependent upon environmental conditions, mainly temperature, moisture and the soil type. Rate of nitrification about doubled for every 10° F increase, based on the averages for a number of soils. Where aqua ammonia was added to the soil at the rate of 100 ppm, from 25 to 50 ppm had oxidized to nitrate in eight weeks even at 37° F and over the same period from 50 to 125

1 A contribution of the Department of Agronomy, University of California at Davis.