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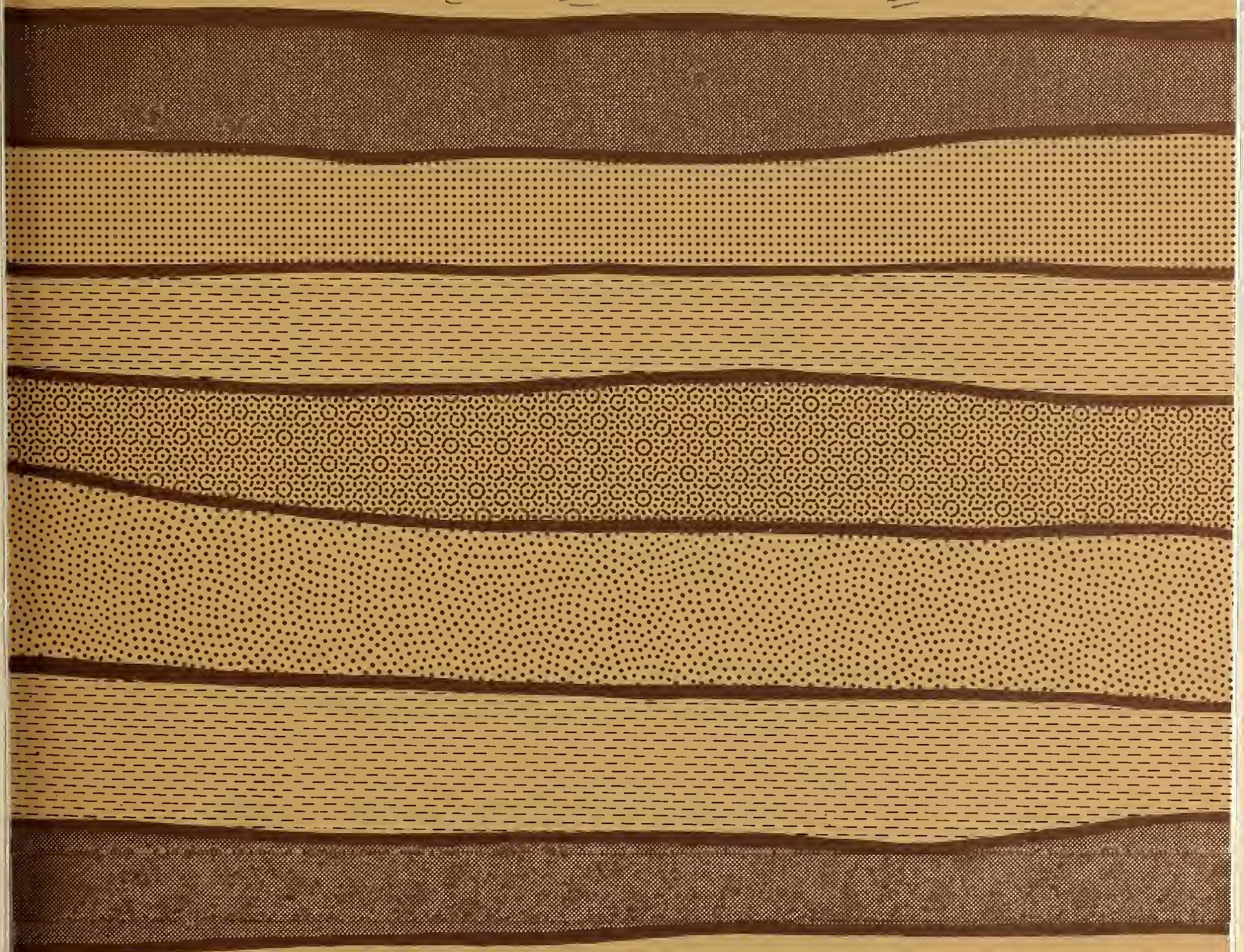
# ORCHARDGRASS RESPONSES TO FERTILIZATION OF SEVEN SURFACE SOILS FROM THE CENTRAL BLUE MOUNTAINS OF OREGON



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## ABSTRACT

*Growth responses to application of all combinations of N, P, and S on four forest and three grassland soils showed that a significant N-S interaction existed for all seven soils. For two grassland soils, a significant response to phosphorus was obtained in combination with nitrogen and sulfur. The volcanic-ash-derived soils and the Klicker soil had the highest potential yield responses to fertilization.*

*Fertilization programs involved with soils which have chemical properties similar to these studied should consider only fertilizer sources which contain both N and S in all cases, and N, S, and P for certain grassland soils.*

Keywords: Fertilization (plants), soil fertility, nitrogen, sulphur.

## INTRODUCTION

The beneficial and detrimental effects of fertilizers in today's highly intensive land management activities are the sources of enthusiasm and concern for their use tomorrow. Proper and appropriate use of fertilizers leads to increased yields, increased profits, improved esthetics, or other benefits. Misuse of fertilizers may lead to environmental depletion of various forms. Therefore it is imperative that the land manager be well informed on both of these use effects prior to fertilizer application on the landscape to be treated.

Little published information exists about the fertilizer response characteristics of upland forest and grassland soils of northeastern Oregon and southeastern Washington. No research has been directed toward identifying specific nutrient deficiencies which might exist in this area. Hedrick et al. (1965) noted large dry matter and protein yield increases for numerous grasses through fertilizer application on a Couse soil in the Wallowa Mountains foothills. Variation in fertilizer benefits was found among species studied and among clipping treatments. Pumphrey (1961, 1963) has studied agricultural crops and soils in relation to plant nutritional requirements.

Predictive quantified knowledge about fertilizer requirements is needed today in relation to many land management activities including forest trail stabilization, increasing timber production, increasing summer forage for livestock, improving logging rehabilitation practices, road cut and fill stabilization, and other erosion and sediment reduction programs.

Several steps are necessary in a research program leading to this prediction capability. The first of these is establishing what nutrient deficiencies may exist for the soil or soils in question. Assays of soil fertility have been made in other areas using biological techniques (Youngberg and Dyrness 1965, Johnson 1969). This method is generally successful and offers an opportunity to compare a number of fertilizers in various combinations over a short period of time using minimal manpower and money. Care in extrapolating these data to the field is necessary, although this also has been successful (Vlamis, Stone, and Young 1954; Wagle and Vlamis 1961).

This study was aimed at determining the major nutrient deficiencies in seven soils found in the Blue Mountains of Oregon.

## METHODS

Surface soil material (0- to 6-inch depth) of seven soil series was collected from locations on the Starkey Experimental Forest and Range, 30 miles southwest of La Grande in Union County, Oregon. Several samplings were from locations of soil survey representative profiles.[1] The soil series were Couse, Klicker, Albee, Anatone (series designation for this soil is currently under reinterpretation but

[1] Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. (Mimeogr.) USDA Soil Conserv. Serv., and USDA Forest Serv. 32 p., 1960.

was mapped as Rock Creek in 1957), Ukiah, Tolo (volcanic ash over a buried B horizon), and another volcanic ash-derived soil. The latter soil series was included in the Tolo series originally but has since been removed from that classification and the new series has not been renamed.[2] This soil was derived from volcanic ash which overlies relatively unweathered basalt bedrock. Characteristics of these soils and their associated vegetation have been documented (Strickler 1965, Geist and Strickler (1970).

Field-soil sample materials were air-dried and passed through a 1/4-inch screen. A subsample of each soil was screened through a 2-millimeter sieve and analyzed chemically prior to the planting process. The gravel content (1/4-inch to 2-millimeter size) of the subsample was determined by weight. The chemical analyses included pH (1:2 in 0.01 M $CaCl_2$), organic matter (Walkley-Black method, Jackson 1958, p. 219-221), extractable K (U.S. Salinity Laboratory staff 1954, p. 100-101), total nitrogen by Kjeldahl (Jackson 1958, p. 187-190), and available P by the sodium bicarbonate method (Watanabe and Olsen 1965).

Fertilizer treatments imposed on each soil were 0 and 100 parts per million each of nitrogen, phosphorus, and sulfur singly and in combination in three replications of a 2 by 2 by 2 by 7 balanced factorial design. Two thousand grams of soil were used in 6-inch pots and de-ionized water was added periodically by weight to maintain moisture tensions in the 1/10- to 1/3-bar range. Plastic bag liners prevented soil and moisture loss, and filler material was used below the bags to equalize the height of the soil surface at the top of the pots. The fertilizer treatment sources were ammonium nitrate, sodium sulfate, and monocalcium phosphate. These were mixed into the dry soil material before initial watering and planting. Seven seeds of Latar orchardgrass (*Dactylis glomerata* L.), a species commonly used in revegetation and soil stabilization, were planted in each pot and were later thinned to five plants. Planting was done January 8, 1970, and plants were harvested 55 days later on March 5.

Mature plants were clipped at the soil surface at harvest, dried for 90 minutes at 100° C., further dried at 60° C. for 24 hours, and then weighed (Mayland 1968).

## RESULTS

The chemical analyses of the surface soils used as experimental material indicated that there were sizable differences among the soils in both chemical and physical status (table 1). Extractable potassium values indicated adequate levels for plant growth in all cases, and pH values differed little among soils. Other analyses will be discussed in relation to greenhouse experimentation.

### Combined Factorial Analyses for All Soils

The initial statistical analyses of treatment effects on plant growth were made for all soils combined, and table 2 is a summary of the analysis of variance. Significance is shown for main effect factors; this is

[2] Personal communication, Grant Lindsay, Soil Conserv. Serv., Baker, Oreg.

Table 1.--*Chemical and physical properties of the surface soils used in the fertilizer study*

| Series sampled | pH | Organic matter | Total nitrogen | Gravel content | Extractable K | Available P |
|---|---|---|---|---|---|---|
| | | Percent | | | Meq./100 g. | P.p.m. |
| Grassland soil: | | | | | | |
| Albee | 5.6 | 2.73 | 0.14 | 19 | 0.6 | 10.4 |
| Anatone (Rock Creek) | 5.4 | 3.87 | .19 | 24 | .6 | 8.4 |
| Ukiah | 5.5 | 4.70 | .21 | 19 | 1.2 | 19.6 |
| Forest soil: | | | | | | |
| Couse | 5.5 | 9.63 | .35 | 22 | 1.1 | 21.8 |
| Klicker | 5.8 | 5.83 | .17 | 37 | 1.8 | 25.2 |
| Tolo | 5.5 | 2.24 | .07 | 12 | 1.3 | 87.0 |
| Ash over basalt | 5.4 | 2.94 | .09 | 16 | .9 | 66.6 |

Table 2.--*Summary table of analysis of variance of orchardgrass dry matter production for all soils and the various combined treatment effects*

| Source | Degrees of freedom | Mean squares | F value |
|---|---|---|---|
| Replication | 2 | 1.67 | -- |
| Soils (So) | 6 | 35.03 | 1/96.83 |
| Nitrogen (N) | 1 | 204.16 | 1/564.32 |
| Sulfur (S) | 1 | 267.02 | 1/738.07 |
| Phosphorus (P) | 1 | 13.83 | 1/38.23 |
| Interactions: | | | |
| SoN | 6 | 10.54 | 1/29.13 |
| SoS | 6 | 4.74 | 1/13.10 |
| SoP | 6 | 1.02 | 2.82 |
| NS | 1 | 190.72 | 1/527.17 |
| NP | 1 | 6.33 | 1/17.50 |
| SP | 1 | 2.19 | 6.05 |
| SoNS | 6 | 4.58 | 1/12.66 |
| SoNP | 6 | .61 | 1.69 |
| SoSP | 6 | .86 | 2.38 |
| NPS | 1 | 5.36 | 1/14.82 |
| SoNSP | 6 | .46 | 1.27 |
| Error | 110 | .36 | -- |

1/ Significant at the 0.01 level.

influenced by the significant interactions shown in the lower portions of the table and not necessarily due to the main effect influence alone. For example, the test of significance of the nitrogen treatment alone involves comparison of the means of all treatments containing nitrogen (including combinations as NS and NPS) as opposed to those lacking nitrogen. Because of significant interaction effects (NS, NPS, etc.), one cannot deduce the influence of nitrogen when no other elements are added. Discussion of individual soils indicates further interaction effects in the data.

The statistical tests indicated significant N and S fertility differences among soils as evidenced by their NS interaction response, and their response to N and S (SoN and SoS, respectively). Over all soils, significant interactions were noted for NS, NP, and NPS sources. The reader can note these effects in later comparisons among individual soil response patterns.

The general conclusion from the above results hence is that fertilizer combinations of N and S or N, P, and S are desirable when looking at the average response over all the soils being studied. The discussion below explains which soils would potentially benefit from these treatment combinations.

## Factorial Analyses of Individual Soils

Results of treatment effects on grass growth for individual soils have been conveniently placed into grassland and forest soil groups. Bar graphs which illustrate the replicate means of grass growth for all treatment combinations are presented. Exemplary photographs of plant growth on some of the soils and treatments have been included with the graphical data. Height growth can be compared using the 6-inch interval scale behind the plants. One should note gray tonal differences in the foliage which are readily visible among the treatments and are a reflection of the coloration symptoms exhibited by the nutrient deficient plants. The greatly increased tillering which occurred in conjunction with growth responses is apparent in some photographs but was not quantified.

### GRASSLAND SOILS

Within the grassland group, grass growth on the Anatone (Rock Creek) and Albee soils showed very similar responses to treatment combinations (figs. 1 and 2). The factorial analyses of variance for the two soils were nearly identical, and both showed significant F-values for all sources tested as shown for the Anatone soil (table 3). The earlier discussion about significant interactions and their relation to main effect tests is amplified when one compares these statistical tests to actual treatment means (fig. 1). Even though the effect of nitrogen alone caused a slight depression in yield, the statistical test of the overall effect of nitrogen on the Anatone soil was significant. This was apparently due to the significant NPS interaction (table 3, fig. 1).

The significant NPS interaction for the Anatone and Albee soils indicates the necessity of using all three fertilizer elements for maximum growth. These were the only soils in either group exhibiting a significant benefit due to phosphorus additions. This would be expected because of their comparatively low analytical level of available phosphorus (table 1). These soils had similar gravel content, hence a similar dilution effect on nutrient content. Field responses to

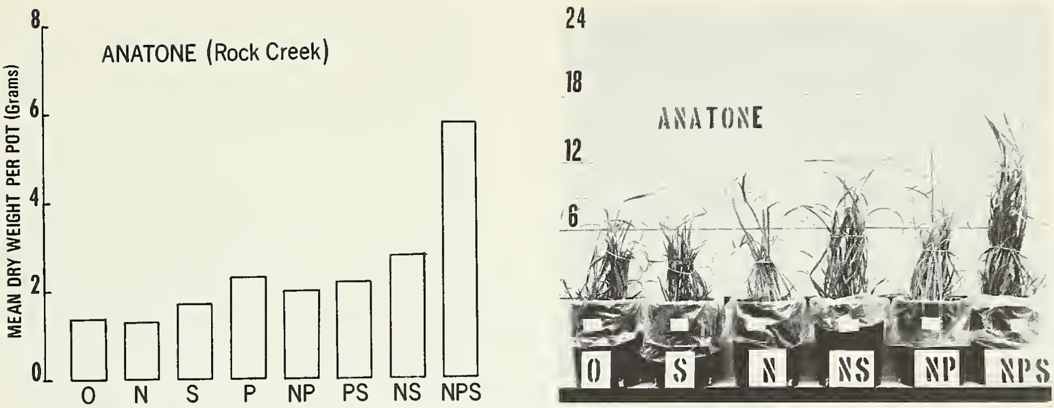


**Figure 1.**—Mean dry matter produced by each fertilizer treatment combination on the Anatone (Rock Creek) soil. The photograph illustrates plant growth with certain treatments.

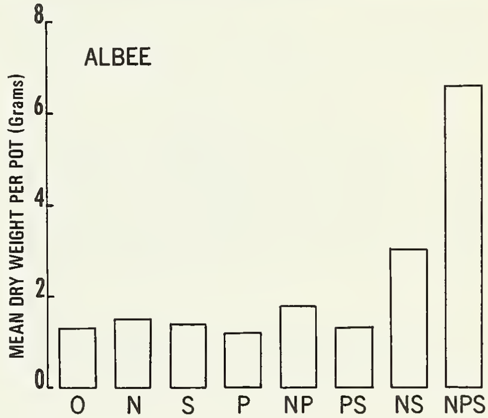


**Figure 2.**—Mean dry matter produced by each fertilizer treatment combination on the Albee soil.

Table 3.--*Analysis of variance of grass growth on the Anatone (Rock Creek) soil*

| Source | Degrees of freedom | Mean squares | F value[1/] |
|---|---|---|---|
| Replication | 2 | 0.64 | -- |
| Nitrogen (N) | 1 | 6.82 | 53.47 |
| Sulfur (S) | 1 | 11.20 | 87.77 |
| Phosphorus (P) | 1 | 9.62 | 75.40 |
| Interactions: | | | |
| NS | 1 | 9.88 | 77.40 |
| NP | 1 | 1.81 | 14.22 |
| PS | 1 | 1.60 | 12.54 |
| NPS | 1 | 2.66 | 20.89 |
| Error | 14 | .12 | -- |

[1/] All are significant at the 0.01 level.

P fertilization should be expected in the 5-10 p.p.m. soil analysis range; however, a response at twice these soil levels (20 p.p.m.) is not uncommon with potted plants in the greenhouse.[3]

The third soil in the grassland group was the Ukiah. Statistical analyses again showed a significant nitrogen-sulfur interaction, but there was no significant effect due to phosphorus. There is also a much higher unfertilized level of growth than found for the other two soils (fig. 3). The latter may be indicative of a higher and better balanced nutrient regime in the Ukiah soil, which had a considerably higher available P level (table 1).

## FOREST SOILS

The Klicker and Couse grass yields showed considerable similarity in their responses to treatments (figs. 4 and 5). There were small-yield increases over the control due to sulfur (S and PS); however, the only meaningful increases were due to the NS and NPS treatments. Factorial statistical analysis indicated a significant (0.01 level) NS interaction response but a nonsignificant effect due to phosphorus for both soils. A tendency for an NPS interaction (F-value = 4.82) was noted in the Klicker yields, hence the greater effect of P. Although analysis for P was higher for the Klicker than the Couse soil, the dilution effect of a greater gravel content in the former was apparently offsetting (table 1).

Both soils derived from volcanic ash exhibited highly significant nitrogen-sulfur interactions with no detectable effects of the phosphorus treatment (figs. 6 and 7). The difference in effects from nitrogen applied alone might be attributed to a lower sulfur level in the Tolo soil which would negate benefits from N applications. These two soils showed the highest potential responses to fertilization among all soils and would each require both nitrogen and sulfur for maximum yield benefits. In contrast,

[3] Personal communication, F.S. Watanabe, USDA Agr. Res. Serv., Dep. Agron., Colo. State Univ., Fort Collins.

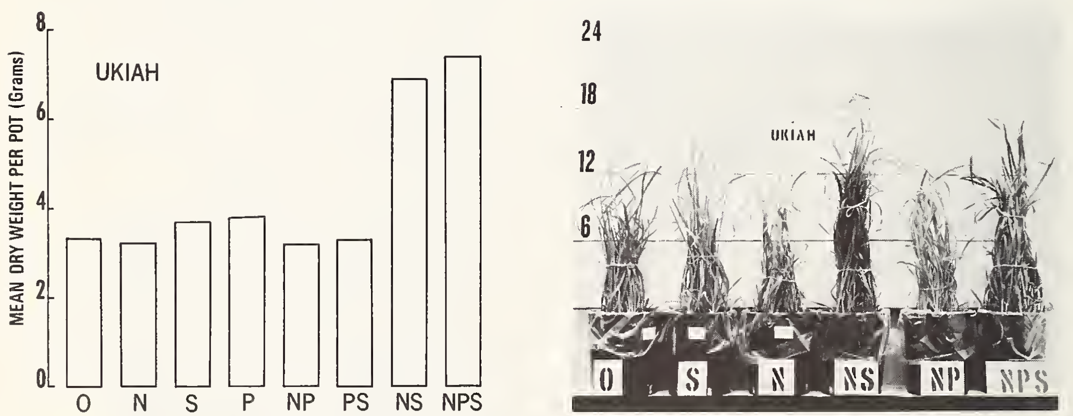


Figure 3.–Mean dry matter produced by each fertilizer treatment combination on the Ukiah soil. The photograph illustrates plant growth with certain treatments.

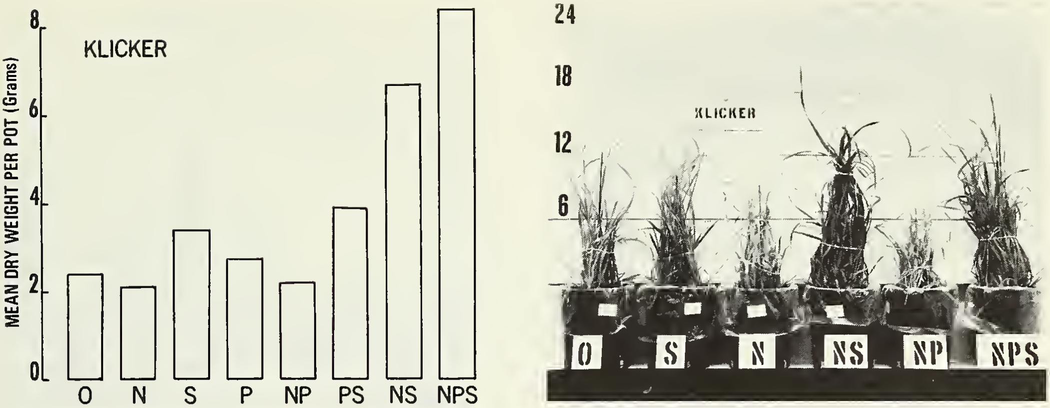


Figure 4.–Mean dry matter produced by each fertilizer treatment combination on the Klicker soil. The photograph illustrates plant growth with certain treatments.

both soils were comparatively low in general fertility status except for available phosphorus values which were quite high (table 1), and their unfertilized yields were the lowest of all soils.

## General Trends

Differences in levels of dry matter produced among soils for unfertilized and fertilized treatments are readily evident (fig. 8). Differences in growth responses (over the control) are easily viewed. Under the NPS and NS treatments, the responses to fertilization were highest on the volcanic ash soils and the Klicker soil. Total production for the NPS treatment was similar among these three and the Couse soil. It is obvious here that the benefits of using nitrogen alone are negative on most soils and insignificant on all soils. Growth responses from phosphorus applications were significant in only two instances (Anatone and Albee grassland soils) and then only in combination with nitrogen and sulfur. The necessity of using nitrogen and sulfur together in all cases is thus emphasized.

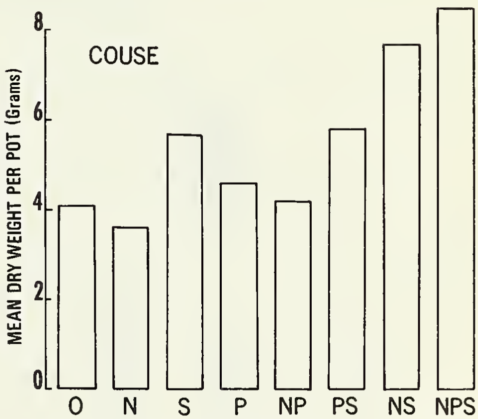


Figure 5.–Mean dry matter produced by each fertilizer treatment combination on the Couse soil.

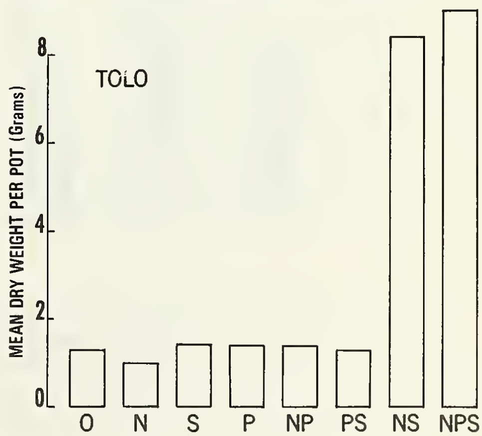


Figure 6.–Mean dry matter produced by each fertilizer treatment combination on the Tolo soil.

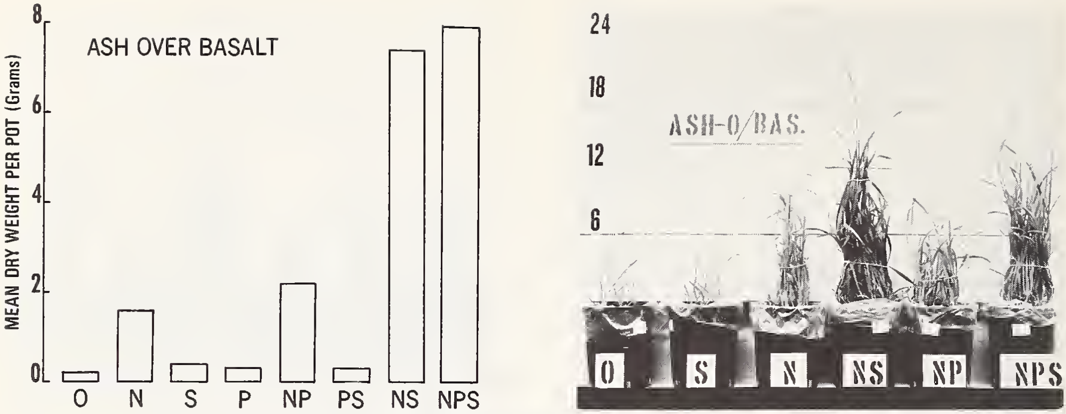


Figure 7.—Mean dry matter produced by each fertilizer treatment combination on the ash over basalt soil. The photograph illustrates plant growth with certain treatments.

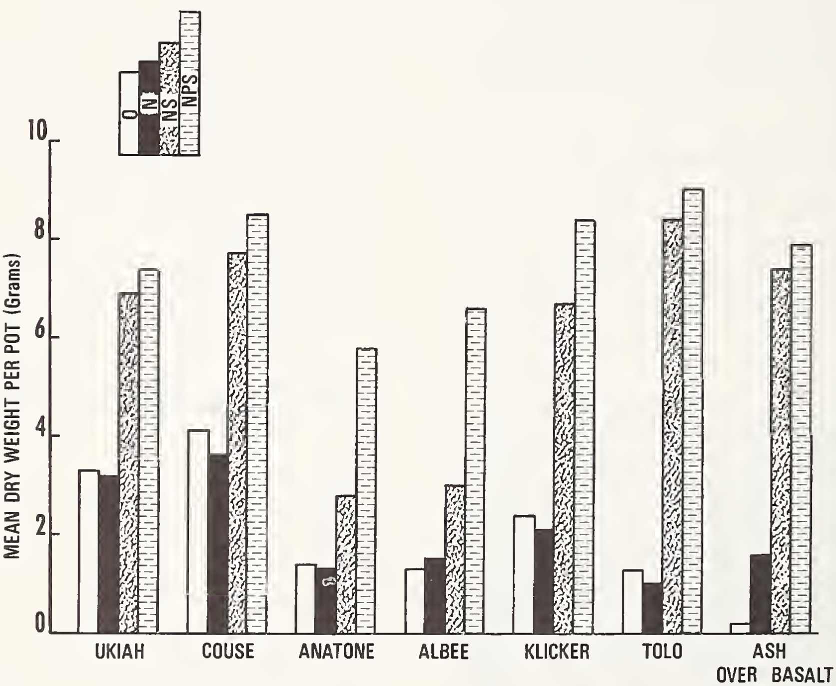


Figure 8.—Growth of orchardgrass on unfertilized and fertilized seven study soils (arranged from left to right in increasing order of response to NPS over control).

a fertilizer program. However, they offer little idea as to appropriate rates, most advantageous source, how the elements should be proportioned, proper time of application, etc. Further research is needed.

## SUMMARY

Interaction responses to fertilization of orchardgrass grown in surface soils collected from seven soil series indicated that both nitrogen and sulfur were necessary to gain significant benefit from additions of either element. Fertilizer sources containing N but lacking S (e. g., urea, ammonium nitrate, potassium nitrate) are not recommended for use on soils with fertility characteristics similar to those studied. The results also showed that for two soils (both grassland soils) the maximum benefit from fertilizing was potentially attainable only by adding phosphorus with nitrogen and sulfur. No other significant phosphorus responses were noted.

Among the seven soils studied, the Klicker and volcanic-ash-derived soils indicated the highest potential yield response to fertilization and should thus give the greatest economic return if site and climatic factors are not otherwise limiting. Soil moisture availability, soil depth, soil temperature, and other factors together with an environmental impact assessment must also be evaluated before a management decision can be made about fertilizer use.

## LITERATURE CITED


Geist, Jon M., and Gerald S. Strickler.
1970. Chemical characteristics of some forest and grassland soils of northeastern Oregon. I. Results from reference profile sampling on the Starkey Experimental Forest and Range. USDA Forest Serv. Res. Note PNW-137, 11 p. Pac. Northwest Forest & Range Exp. Sta., Portland, Oreg.

Hedrick, D. W., J. A. B. McArthur, J. E. Oldfield, and J. A. Young.
1965. Seasonal yield and chemical content of forage mixtures on a pine woodland meadow site in northeastern Oregon. Oreg. State Univ. Agr. Exp. Sta. Tech. Bull. 84, 42 p.

Jackson, M. L.
1958. Soil chemical analysis. 498 p., illus. Englewood Cliffs, N. J.: Prentice-Hall, Inc.

Johnson, W. M.
1969. Pot tests indicate fertilizers can improve soils from Black Mesa in western Colorado. USDA Forest Serv. Res. Note RM-153, 4 p. Rocky Mt. Forest & Range Exp. Sta., Fort Collins, Colo.

Mayland, H. F.
1968. Effect of drying methods on losses of carbon, nitrogen and dry matter from alfalfa. Agron. J. 60: 658-659.

Pumphrey, F. V.
1961. Winter wheat fertilization in northeast Oregon. Oreg. State Univ. Agr. Exp. Sta. Circ. Inform. 610, 8 p.

__________
1963. Sulfur and phosphorus fertilization of alfalfa and clover in northeast Oregon. Oreg. State Univ. Agr. Exp. Sta. Circ. Inform. 619, 10 p.

__________
1971. Grass species growth on a volcanic ash-derived soil cleared of forest. J. Range Manage. 24: 200-203.

Strickler, Gerald S.
1965. Soil and vegetation on the Starkey Experimental Forest and Range. Soc. Amer. Forest. Proc. 1965: 27-30.

U.S. Salinity Laboratory Staff.
1954. Diagnosis and improvement of saline and alkali soils. U.S. Dep. Agr. Agr. Handb. 60, 160 p.

Vlamis, J., E. C. Stone, and C. L. Young.
1954. Nutrient status of brushland soils in southern California. Soil Sci. 78 (1): 51-55, illus.

Wagle, R. F., and J. Vlamis.
1961. Nutrient deficiencies in two bitterbrush soils. Ecology 42: 745-752, illus.

Watanabe, F. S., and S. R. Olsen.
1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Amer. Proc. 29: 677-678.

Youngberg, C. T., and C. T. Dyrness.
1965. Biological assay of pumice soil fertility. Soil Sci. Soc. Amer. Proc. 29: 182-187.

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Keywords: Fertilization (plants), soil fertility, nitrogen, sulphur.

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