Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A 279.9
Ag8
Con. Re, Rep. #11

Productivities of Horizons of Seven Benchmark Soils of the Southern Great Plains

Conservation Research Report No. 11

LIBRARY
RECEIVED
JAN 8 1968
U.S. DEPARTMENT OF AGRICULTURE
BELTSVILLE BRANCH

Agricultural Research Service
U. S. DEPARTMENT OF AGRICULTURE

In Cooperation With

Texas Agricultural Experiment Station

CONTENTS

Washington, D.C. Issued November 1967

For sale by the Superintendent of Documents U.S. Government Printing Office
Washington, D.C. 20402 - Price 20 cents

Productivities of Horizons of Seven Benchmark Soils of the Southern Great Plains

By Harold V. Eck, *research soil scientist;* Robert H. Ford, *agricultural research technician;* and Carl D. Fanning, *research soil scientist; Soil and Water Conservation Research Division, Agricultural Research Service*

When moisture conservation practices such as bench leveling or land shaping are used, topsoil is removed and subsoil is exposed. Under these conditions, productivity of the subsoil becomes highly important. Restoration of subsoil productivity determines the amount of topsoil removal that is permissible or whether a given land-shaping practice is feasible.

Studies reported in this report (1) assessed relative productivities of genetic horizons of seven soil types from the Amarillo, Miles, Dalhart, Reinach, Grant, Abilene, and Spearville series in the Southern Great Plains, and (2) determined plant nutrient needs for maximum yields on various soil horizons. This information can be used in judging the feasibility of land forming and in predicting the fertilizer treatments required to restore productivity after land forming.

Many researchers have found that deficiencies of nitrogen, phosphorus, and potassium were principally responsible for reduced yields from subsoils (*1, 5, 6, 9, 12, 17, 18, 20*).[1] Others have found that in addition to the macronutrients, organic amendments (*10*) or zinc (*8, 14*) was required before yields on subsoils approached those on topsoils. In related growth chamber and field experiments, Carlson and Grunes (*2*) and Carlson and others (*3*) found that with inorganic fertilizers, yields on fertilized C horizon of Gardena soil approached but did not equal those attained on fertilized A horizon. When nitrogen, phosphorus, zinc, and manure were applied, yields from subsoil and surface soil were equal. When surface soil was mixed with subsoil during the land leveling operations, the need for phosphorus fertilizer was reduced.

---

[1] Italic numbers in parentheses refer to Literature Cited, p. 35.

In a greenhouse study on Keiser soil and in field studies on Keiser and Nunn soils, Reuss and Campbell (*16*) obtained similar yields on nitrogen- and phosphorus-fertilized topsoil and subsoil.

Eck, Hauser, and Ford (*6*) studied Pullman silty clay loam in greenhouse and field experiments. Under high nitrogen and phosphorus levels, the 28- to 38-inch horizon produced yields equivalent to surface soil and greater than all other depths studied. In the field, nitrogen and phosphorus restored productivity where up to 12 inches of topsoil were removed. Yields on heavily fertilized 16-inch cuts were 80 percent of those on similarly fertilized, undisturbed soil.

EXPERIMENTAL PROCEDURE

Profiles of seven different soil types were studied in successive greenhouse experiments at the Southwestern Great Plains Research Center, Bushland, Tex. Soils studied were Amarillo fine sandy loam, Miles fine sandy loam, Dalhart fine sandy loam, Reinach loam, Grant silt loam, Abilene silty clay loam, and an uncorrelated silty clay loam tentatively called Spearville.[2] Sampling sites, brief profile descriptions, and soil chemical and physical data are presented in the Appendix (tables 2 to 22). More complete profile, chemical, and physical data for the Amarillo, Miles, and Grant soils have been presented by Mathers and others (*13*).

Phosphorus equilibration studies were conducted on all seven soils but were used in determining phosphorus rates on only Grant, Spearville, and Reinach. Laboratory equilibration of phosphorus with soil consisted of mixing given rates of phosphorus (as KH_2PO_4 solution) with aliquots of soil, subjecting the soil to seven wetting and drying cycles, and then analyzing it for sodium bicarbonate-soluble phosphorus (*15*). Four replicate aliquots of soil were treated and analyzed for each depth of each soil used. In figures 1 to 7, plots show increase in sodium bicarbonate-soluble phosphorus when different rates of phosphorus were added to the seven different soils. Values on the graphs are averages of the four replicate samples.

Six depth horizons of soil from each profile were studied under nine fertilizer treatments. Generally, each depth horizon corresponded to one genetic horizon; however, where genetic horizons were rather thick, they were split into two increments. Depth increments of split horizons are labeled "a" and "b" in horizon

[2] The soil is referred to as Spearville silty clay loam in this publication.

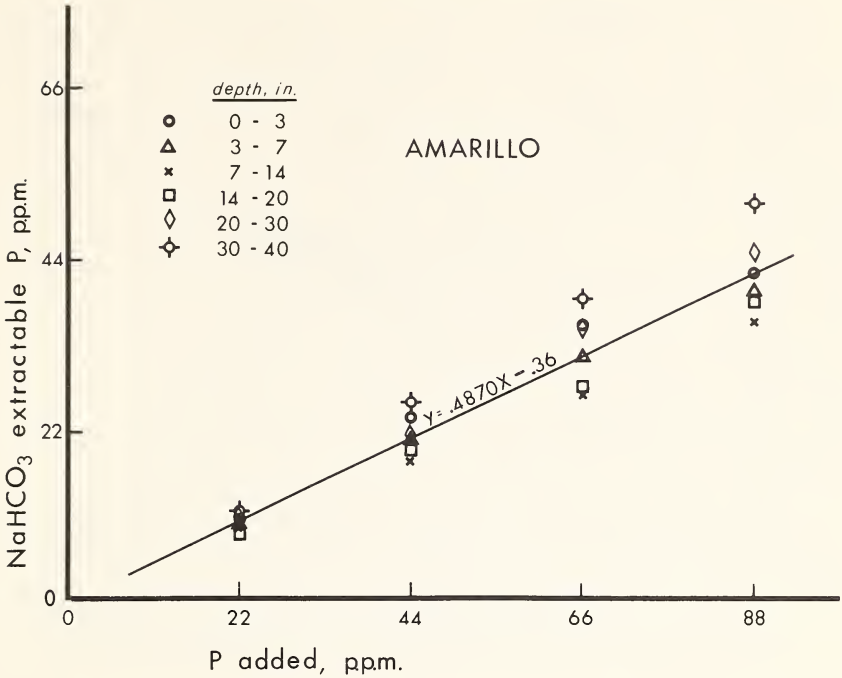

FIGURE 1.—Phosphorus equilibration curve for Amarillo fine sandy loam.

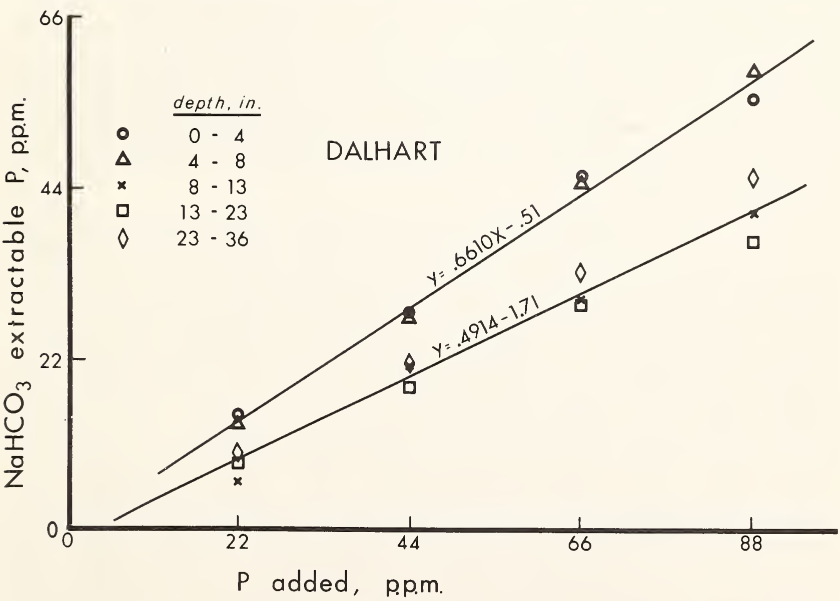

FIGURE 2.—Phosphorus equilibration curve for Dalhart fine sandy loam.

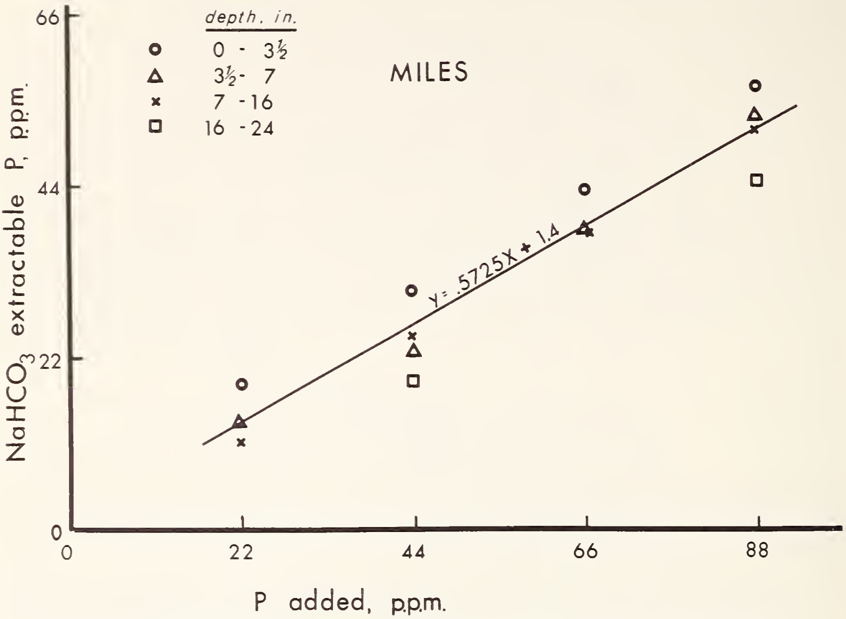

FIGURE 3.—Phosphorus equilibration curve for Miles fine sandy loam.

designations in tables and figures. On one soil (Dalhart), a mixture of two horizons (one-half Alp, one-half B22) was studied under various fertilizer treatments. The nine fertilizer treatments consisted of a complete factorial of three rates of nitrogen and three rates of phosphorus. Fertilizer sources were ammonium nitrate and concentrated superphosphate. Each treatment was replicated four times.

On all soils, nitrogen rates were 0, 250, and 500 pounds per acre ($2x10^6$ lb. of soil). On Amarillo, Miles, Dalhart, and Abilene soils, phosphorus rates were 0, 66, and 132 pounds per acre ($2x10^6$ lb. of soil). On Spearville, Grant, and Reinach soils, phosphorus additions were calibrated to adjust sodium bicarbonate-soluble phosphorus to predetermined levels. On Spearville and Grant soils, the three phosphorus levels were the initial levels and 26- and 35-pound levels of sodium bicarbonate-soluble phosphorus per acre ($2x10^6$ lb. of soil). On Reinach, phosphorus levels were adjusted to 52 and 70 pounds of sodium bicarbonate-soluble phosphorus per acre ($2x10^6$ lb. of soil). Required amounts of fertilizer phosphorus were determined by subtracting the amount of sodium bicarbonate-soluble phosphorus in the soil from the desired level and multiplying the remainder by a factor (the reciprocal of the regression of sodium bicarbonate-soluble phosphorus on applied phosphorus) that had been derived from laboratory equilibration of phosphorus with soil.

Nine-pound aliquots (Reinach soil) or ten-pound aliquots (all other soils) of air-dry soil were mixed with necessary amounts of fertilizer in a twin-shell blender and potted in 8-inch, unglazed, clay flower pots. The soil was wetted by capillarity and then allowed to dry sufficiently for planting.

German millet (*Setaria italica*) was planted and thinned to 20 plants per pot after emergence. Thinned plants were left on the soil surface in their respective pots. Plants were watered by capillarity as necessary. Millet was harvested when plants on the better treatments approached "boot" stage. Slower growing plants on other treatments remained in the vegetative stage.

The experiments were conducted during the frost-free season in an unheated greenhouse; thus, lengths of growth periods were affected by weather conditions. Dates of planting, harvest, and lengths of growth periods are presented in table 1. The long growth period and the low yields on Abilene soil (see fig. 23) resulted from cool nights late in the growing season.

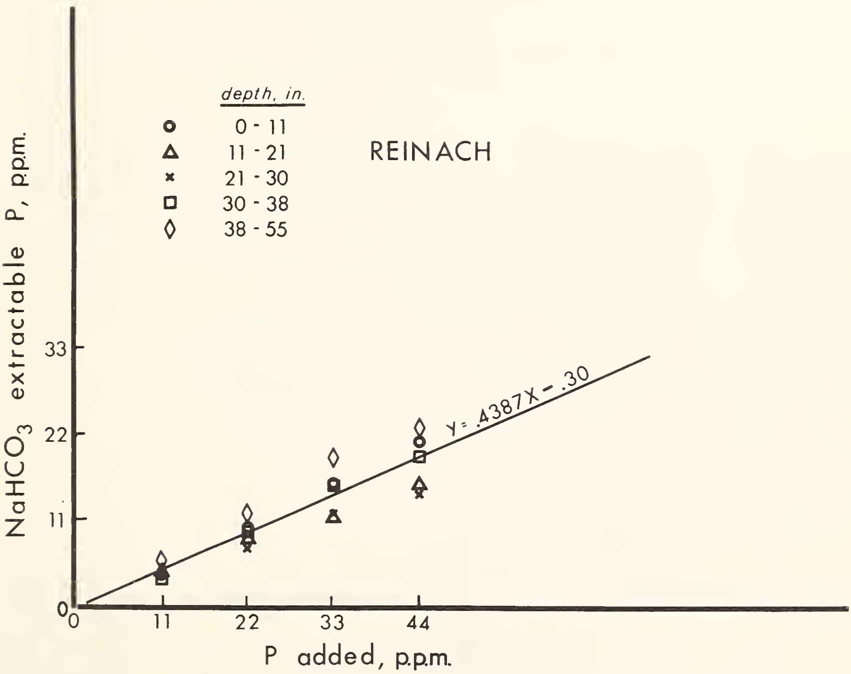

FIGURE 4.—Phosphorus equilibration curve for Reinach loam.

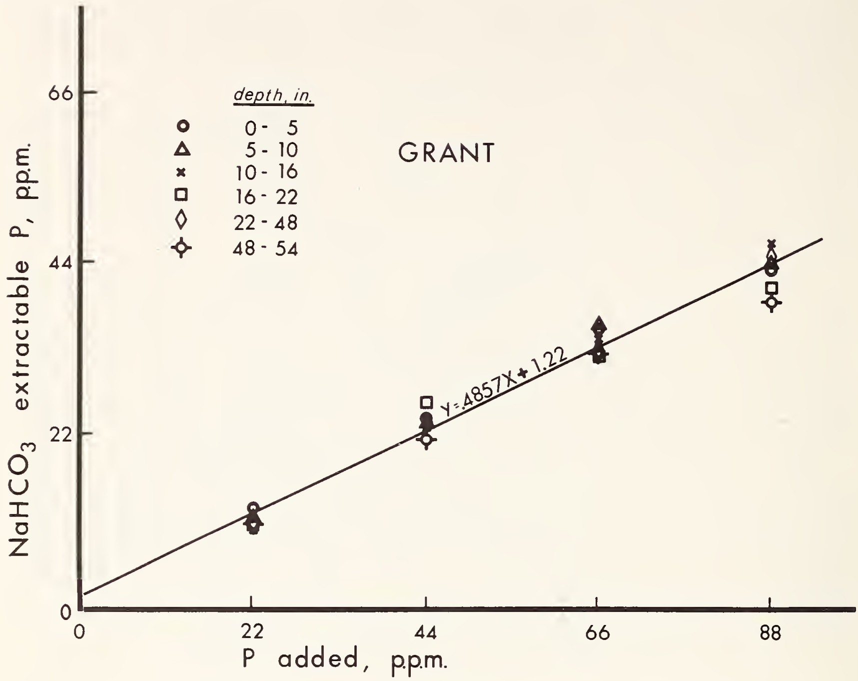

FIGURE 5.—Phosphorus equilibration curve for Grant silt loam.

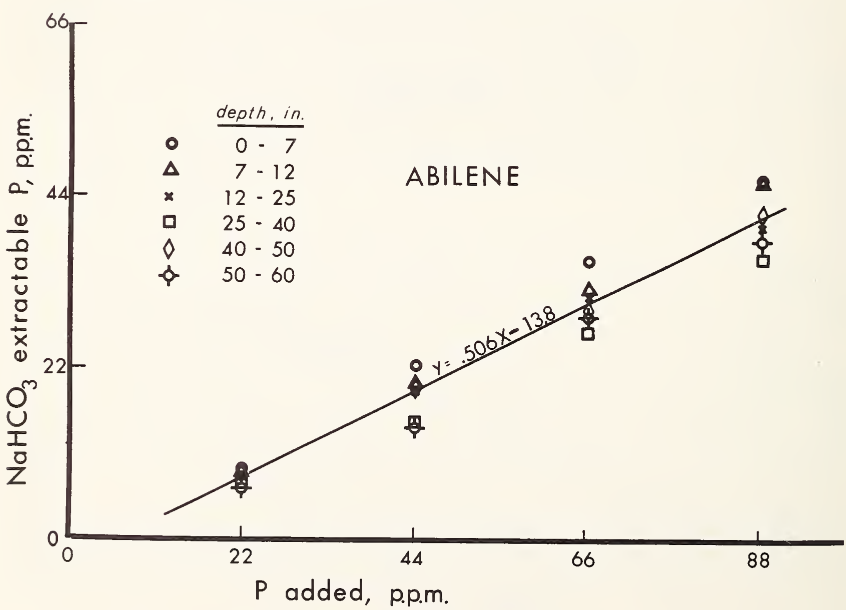

FIGURE 6.—Phosphorus equilibration curve for Abilene silty clay loam.

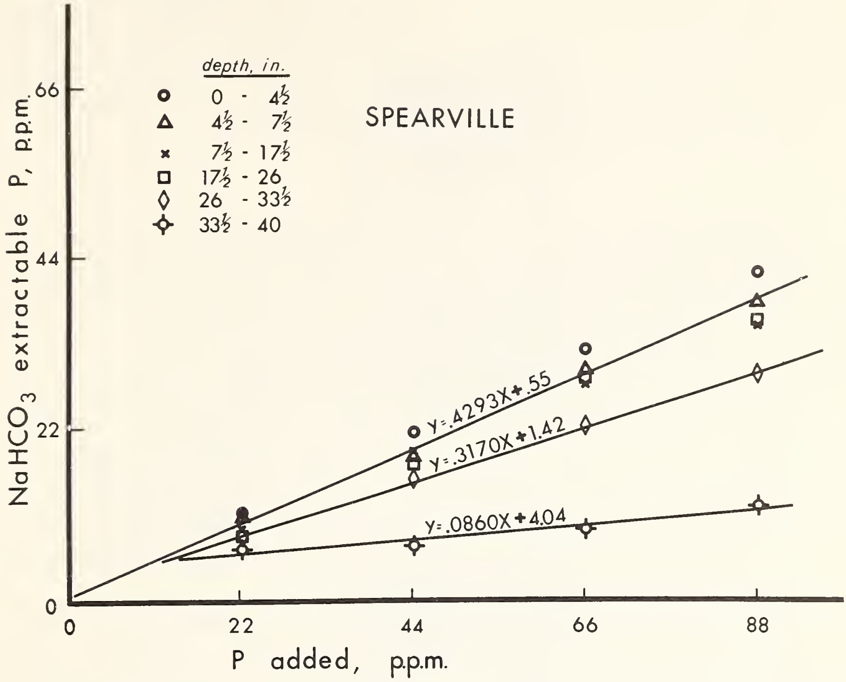

FIGURE 7.—Phosphorus equilibration curve for Spearville silty clay loam.

Harvested samples were ovendried at 70° C., weighed, and analyzed for nitrogen and phosphorus content by methods outlined by Jackson (*11*). Because of the low yields, samples grown on Abilene soil were not analyzed.

TABLE 1.—*Planting and harvesting dates and growth periods of millet on the various soils*

Soil	Planting date	Harvesting date	Growth period
			Days
Amarillo	9/1/59	9/28/59	27
Miles	8/25/60	9/30/60	36
Dalhart	6/6/60	7/14/60	38
Reinach	7/3/61	8/8/61	36
Grant	8/22/62	10/5/62	44
Abilene	9/13/61	11/3/61	51
Spearville	6/26/62	8/2/62	37

Yield data were subjected to analysis of variance (*19*), and, where significant F values were obtained (5-percent level), treatment means were subjected to Duncan's multiple range test (*4*). All statements regarding differences in yields are based on statistical significance at the 95-percent probability level.

RESULTS

In the graphs relating applied phosphorus to increase in sodium bicarbonate-soluble phosphorus (figs. 1 through 7), only one regression equation was calculated for each soil profile when there were only minor differences between horizons. However, when phosphorus retention varied significantly among horizons, separate equations were calculated for horizons that were similar in phosphorus retention. The two surface horizons of Dalhart were similar to each other but different from the other depths. On Spearville, the 26- to 33½- and 33½- to 40-inch depths each retained more phosphorus than the horizons above them. On all other soils, single regression equations adequately describe phosphorus retention on all soil horizons.

Forage yield and plant phosphorus and nitrogen data for each soil are presented together so that details for each soil can be kept separate. In the analysis of yield data by individual horizons in the various soils, nitrogen × phosphorus interactions (where additions of one element materially changed the yield obtained with the other element) were found in many instances. For this reason, and because the high levels of nitrogen and phosphorus seldom decreased yields, response to each element is interpreted in the presence of the highest level of the other.

Amarillo Fine Sandy Loam

Yield data for Amarillo fine sandy loam are presented in figure 8. Without fertilizer, soil from the 0- to 3-inch depth produced higher yields than soil from any other depth. However, when highest yielding treatments from each of the depth horizons are compared, higher yields were produced on the 7- to 14- and 14- to 20-inch depths than on the 0- to 3- and 3- to 7-inch depths. Maximum yields on the 20- to 30- and 30- to 40-inch depths were not different from those on other depth horizons.

Nitrogen × phosphorus interactions were found in yield data from all depth horizons. Nitrogen or phosphorus alone did not produce yields different from the check treatment, but all combinations of nitrogen and phosphorus yielded more than treatments receiving no fertilizer or nitrogen or phosphorus alone. Within

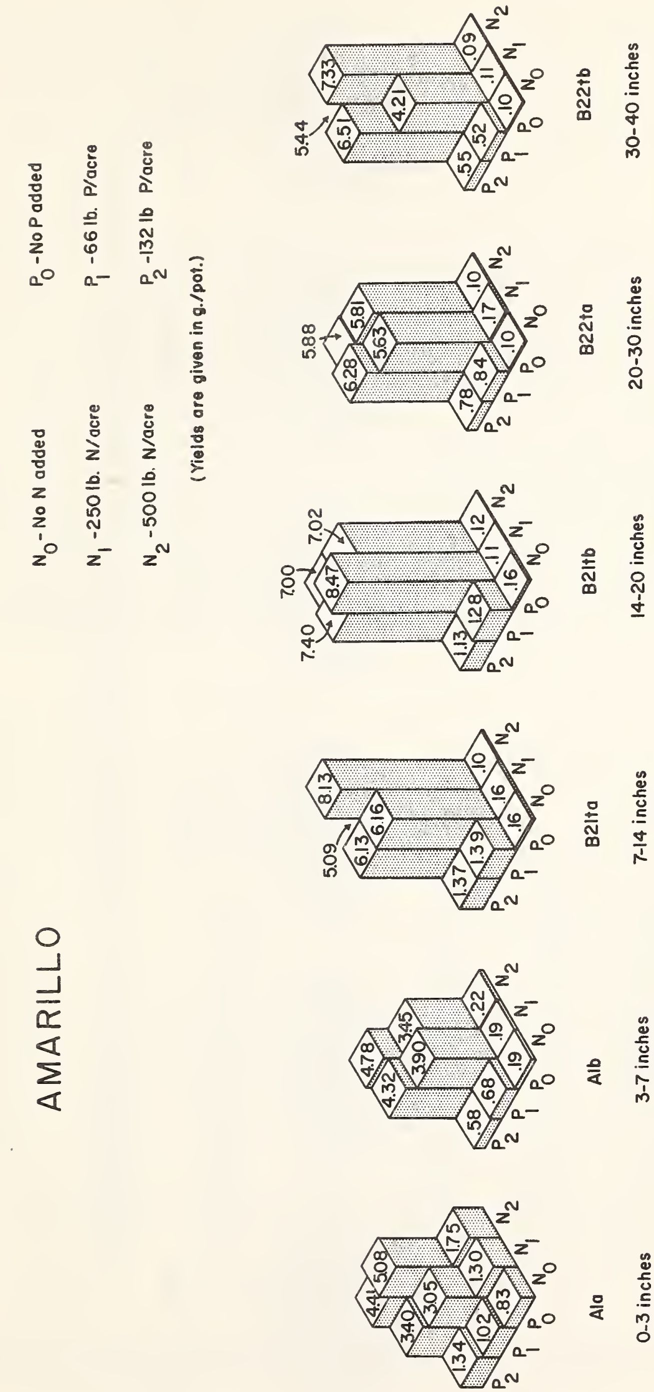

FIGURE 8.—Effect of fertilizer treatments on yields of millet produced on different horizons of Amarillo fine sandy loam.

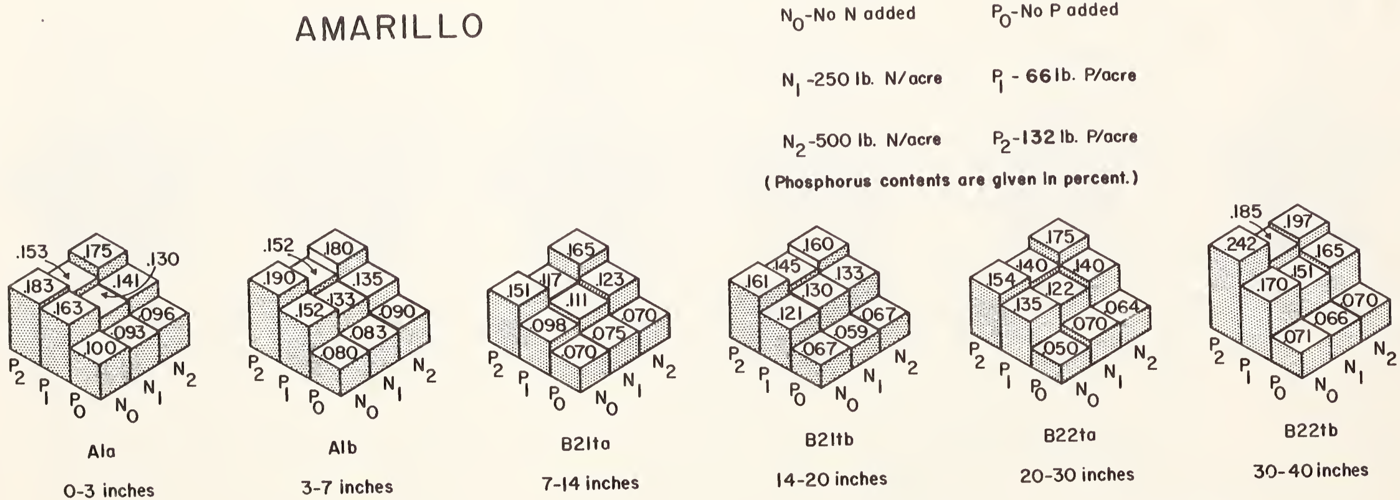

FIGURE 9.—Effect of fertilizer treatments on phosphorus content of millet tops grown on different horizons of Amarillo fine sandy loam.

soil depths, the four nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 0- to 3-inch depth: N_1P_1 yielded less than N_2P_1 and N_2P_2, N_1P_2 yielded less than N_2P_1; (2) 3- to 7-inch depth: N_2P_1 yielded less than N_2P_2; (3) 7- to 14-inch depth: N_2P_1 outyielded all others; and (4) 30- to 40-inch depth: N_1P_1 yielded less than N_2P_1.

Phosphorus content increased with increasing rates of applied phosphorus on all soil depths (fig. 9). The low phosphorus contents where no phosphorus was applied reflect the low levels of available phosphorus in the soil. Since the high phosphorus treatments did not materially increase yields, plant phosphorus levels higher than those obtained with the intermediate phosphorus treatment probably reflect luxury consumption.

Nitrogen content of the plant tissue is presented in figure 10. Samples were insufficient for nitrogen determinations on the N_0P_2 treatment except on the 0- to 3-inch soil depth. The available data show that nitrogen contents increased when the nitrogen applications were increased from the N_1 to the N_2 level. Results were substantially the same on all soil depth horizons.

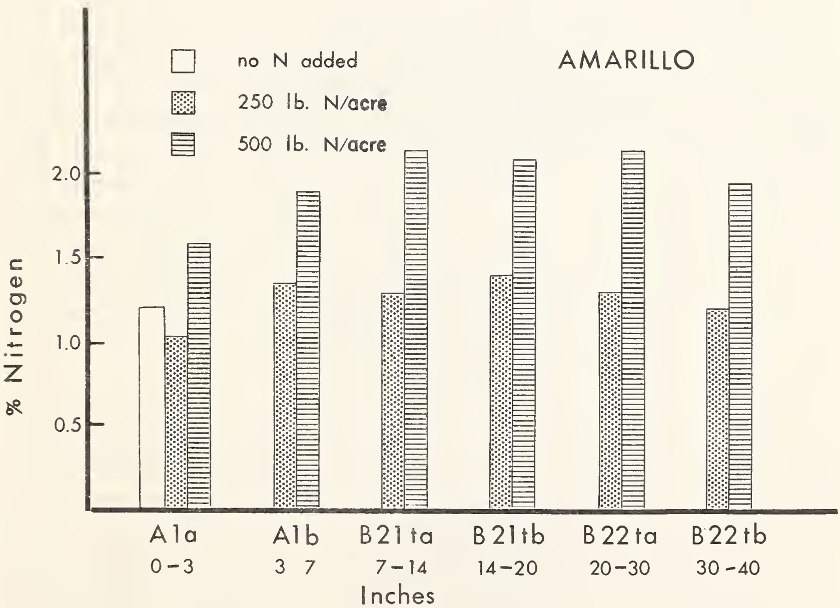

FIGURE 10.—Effect of nitrogen rates on nitrogen content in millet tops grown on different horizons of Amarillo fine sandy loam.

Dry matter yields and nitrogen and phosphorus analyses on forage samples indicated that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on all soil depths. Productivities of the subsurface horizons were increased to levels equal to or greater than the level on the surface horizon.

Dalhart Fine Sandy Loam

Yield data for the Dalhart fine sandy loam are presented in figure 11. Without fertilizer soil from the 0- to 4-inch depth produced the highest yields. However, when highest yielding treatments from each of the depth horizons are compared, soil from the 8- to 13-inch depth produced the most forage. Soil from the 13- to 23-inch and 4- to 8-inch depths produced higher yields than that from the 0- to 4-inch depth. After fertilization, the yield on the mixture of soil from the 0- to 4-inch and 13- to 23-inch depths was equal to the yields on the 8- to 13-inch and 13- to 23-inch depths and greater than those on the other three depths studied.

Nitrogen × phosphorus interactions were measured on all depth horizons studied. Nitrogen alone increased yields only on soil containing the 0- to 4-inch horizon (0- to 4-inch and 0- to 4-, 13- to 23-inch mixture). Phosphorus alone increased yields on the 8- to 13-, 13- to 23-, and 23- to 36-inch depths. Nitrogen and phosphorus in combination, however, gave yield increases on all depths. Within soil depths, the four nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 0- to 4-inch depth: N_1P_2 yielded less than the other three; (2) 4- to 8-inch depth: N_1P_1 yielded less than N_2P_1 and N_2P_2, N_2P_2 outyielded all other treatments; (3) 13- to 23-inch depth: N_1P_2 outyielded all other treatments; and (4) mixture of 0- to 4- and 13- to 23-inch depths: N_1P_1 yielded less than the other three treatments, N_1P_2 yielded less than N_2P_1 and N_2P_2.

Phosphorus content of the plant tissue (fig. 12) increased with increasing rates of applied phosphorus on most soil depths, especially those on which the initial levels of plant-available phosphorus were low. On most soil depths, applied nitrogen decreased phosphorus content of the plant tissue. This resulted from increased plant growth from applied nitrogen and subsequent dilution of phosphorus rather than from decreased phosphorus uptake.

Nitrogen content of the plant tissue is presented in figure 13. Nitrogen contents increased when nitrogen applications were

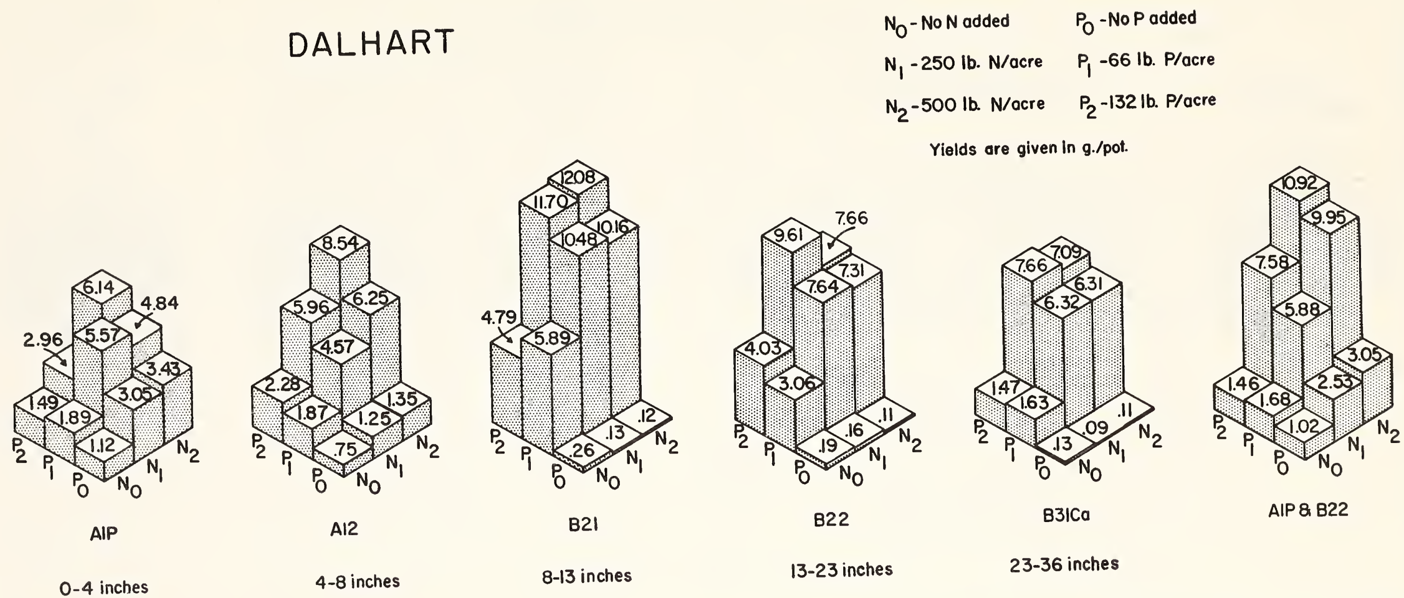

FIGURE 11.—Effect of fertilizer treatments on yields of millet produced on different horizons of Dalhart fine sandy loam.

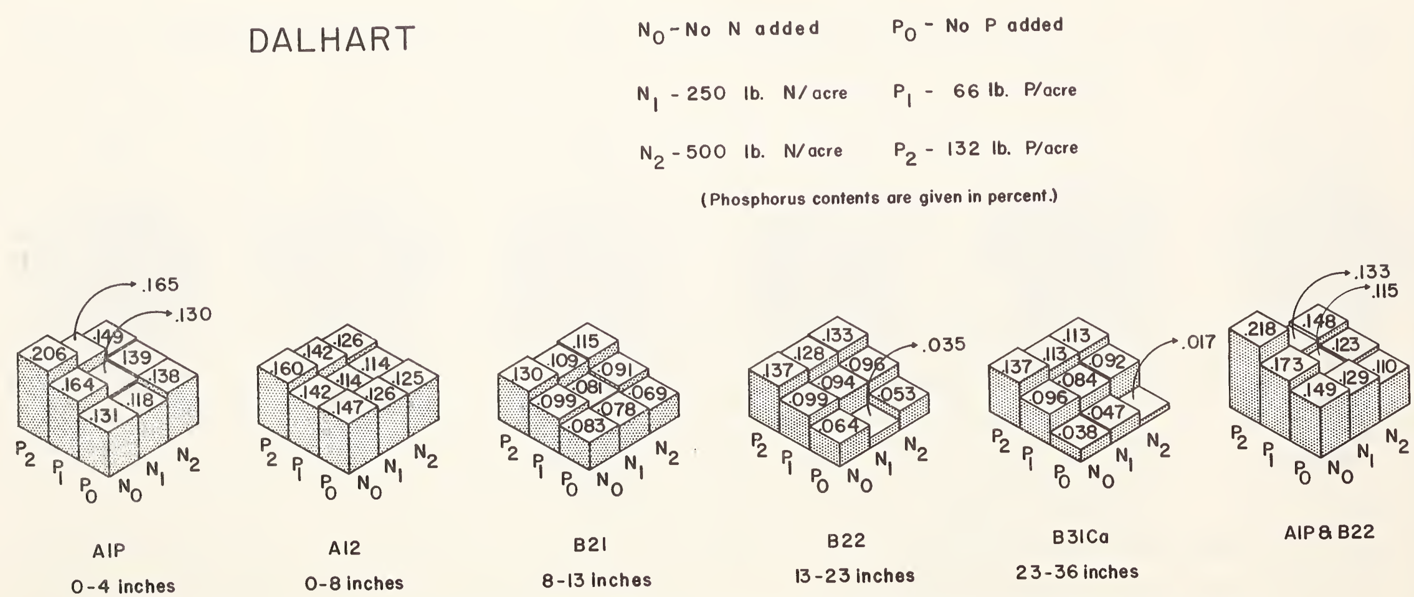

FIGURE 12.—Effect of fertilizer treatments on phosphorus content of millet tops grown on different horizons of Dalhart fine sandy loam.

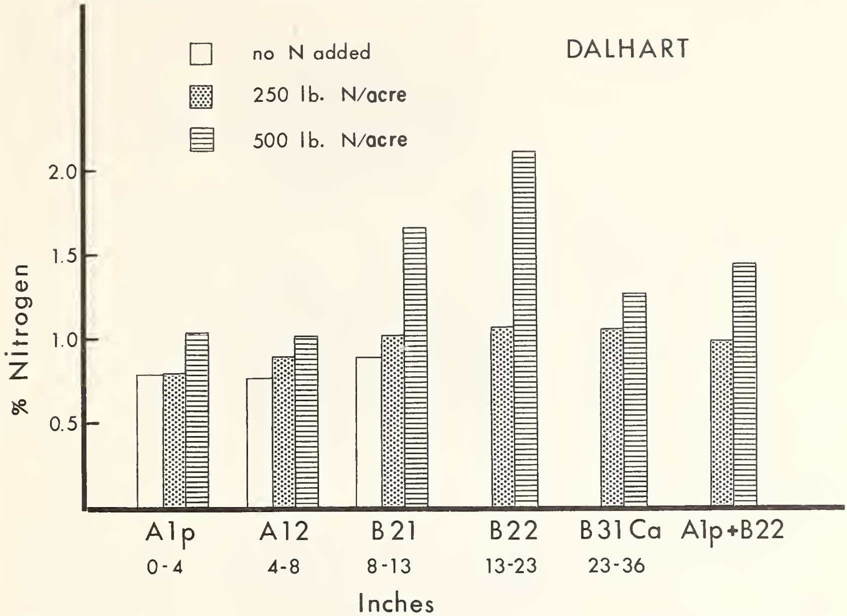

FIGURE 13.—Effect of nitrogen rates on nitrogen content in millet tops grown on different horizons of Dalhart fine sandy loam.

increased from the N_1 to the N_2 level. Like increments of nitrogen produced larger increases in nitrogen contents on soil from the 8- to 13- and 13- to 23-inch depths than on soil from the other depths.

Dry matter yields and nitrogen and phosphorus analyses on forage samples indicated that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on all soil depths. Productivities of the subsurface horizons were increased to levels equal to or greater than the level on the surface horizon. A mixture of soil from the 0- to 4-inch and 13- to 23-inch depths was more productive than soil from the 0- to 4-inch depth alone.

Miles Fine Sandy Loam

Yield data for the Miles fine sandy loam are presented in figure 14. Miles soil reacted very much like Amarillo and Dalhart. Without fertilizer, the surface horizon was the most productive; but with nitrogen and phosphorus, the finer textured subsurface horizons produced yields equal to or greater than those produced

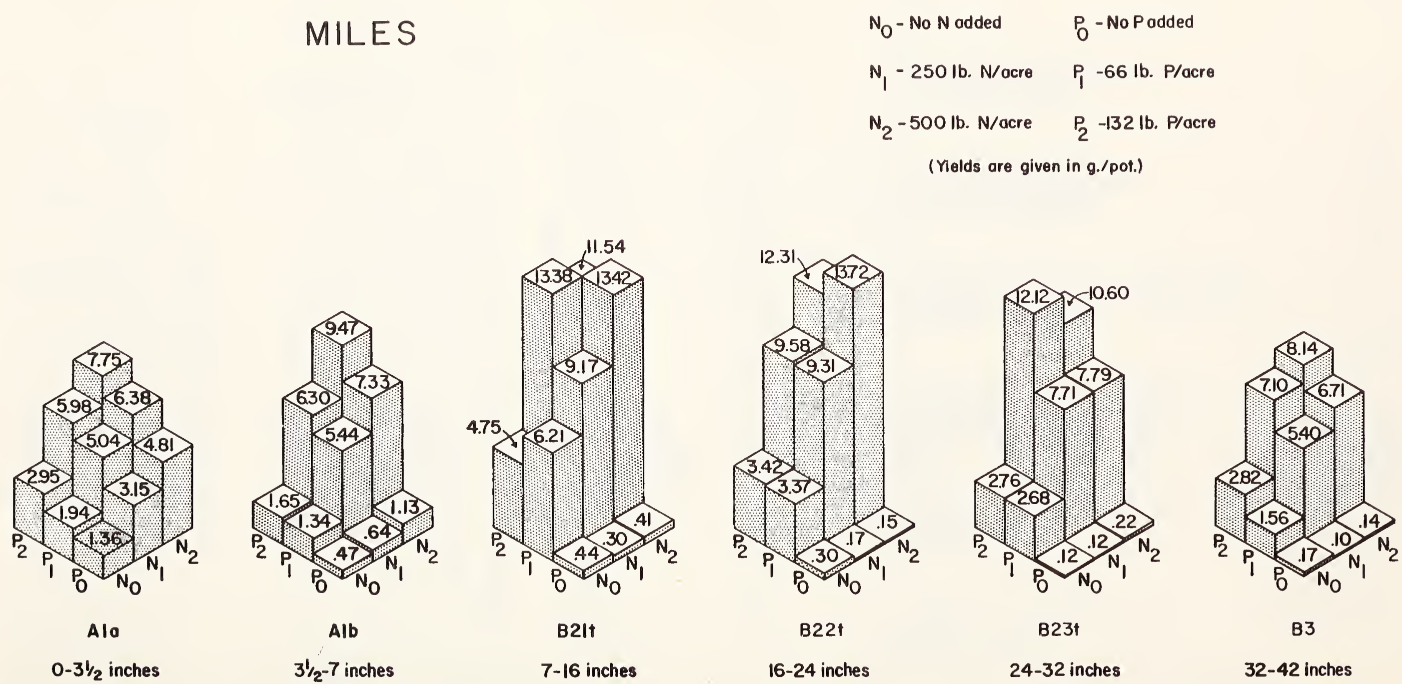

FIGURE 14.—Effect of fertilizer treatments on yields of millet produced on different horizons of Miles fine sandy loam.

on the surface soil. A comparison of highest yielding treatments from each soil depth shows that the 7- to 16-, 16- to 24-, and 24- to 32-inch depth horizons produced higher yields than the surface horizon. Maximum yields on the 3½- to 7- and 32- to 42-inch depth horizons were not different from those on the surface horizon.

Nitrogen × phosphorus interactions were observed on the 3½- to 7-, 16- to 24-, and 24- to 32-inch depths. Phosphorus alone affected yields more than nitrogen alone on all except the surface horizon. Nitrogen alone increased yield on the surface horizon only, while phosphorus alone increased the yield on the 7- to 16- and 16- to 24-inch horizons. Nitrogen and phosphorus in combination increased yields on all horizons. Within soil depths, the four nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 0- to 3½-inch depth: N_1P_1 yielded less than N_2P_2; (2) 3½- to 7-inch depth: N_2P_2 outyielded N_1P_1 and N_1P_2; (3) 7- to 16-inch depth: N_1P_1 yielded less than N_1P_2 and N_2P_1; (4) 16- to 24-inch depth: N_2P_2 and N_2P_1 outyielded N_1P_1 and N_1P_2; and (5) 24- to 32-inch depth: N_1P_2 outyielded N_1P_1 and N_2P_1. The results show that the P_1 rate was sufficient for maximum yields on all soil depths; but, under the conditions of this experiment, nitrogen rates higher than 250 pounds per acre were required for maximum yields on some soil depths.

Phosphorus content of the plant tissue (fig. 15) increased with increasing increments of applied phosphorus, especially on the subsurface horizons. Low phosphorus contents, where no phosphorus was applied, reflect the low levels of available phosphorus in this soil. Since the P_2 phosphorus level did not increase dry matter yields over those obtained with the P_1 level, increased phosphorus contents (P_2 over P_1) probably reflect luxury consumption of phosphorus. Plants grown on the surface horizon were higher in phosphorus than those grown on the other horizons. Applied nitrogen decreased plant phosphorus content on the surface horizon.

Plant nitrogen content (fig. 16) was not affected by applied nitrogen on the 0- to 3½- and 3½- to 7-inch horizons but was increased by added nitrogen on the other horizons.

Dry matter yields and nitrogen and phosphorus analyses on the plant tissue show that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on soil from all depths. Productivities of the subsurface horizons were increased to levels equal to or greater than the level on the surface horizon.

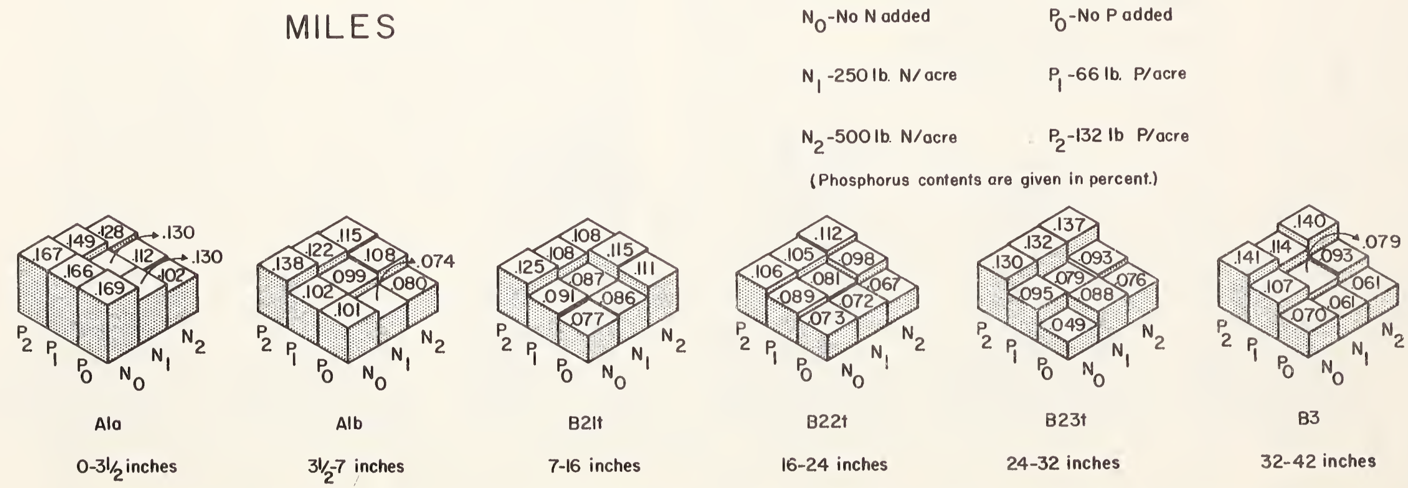

FIGURE 15.—Effect of fertilizer treatments on phosphorus content of millet tops grown on Miles fine sandy loam.

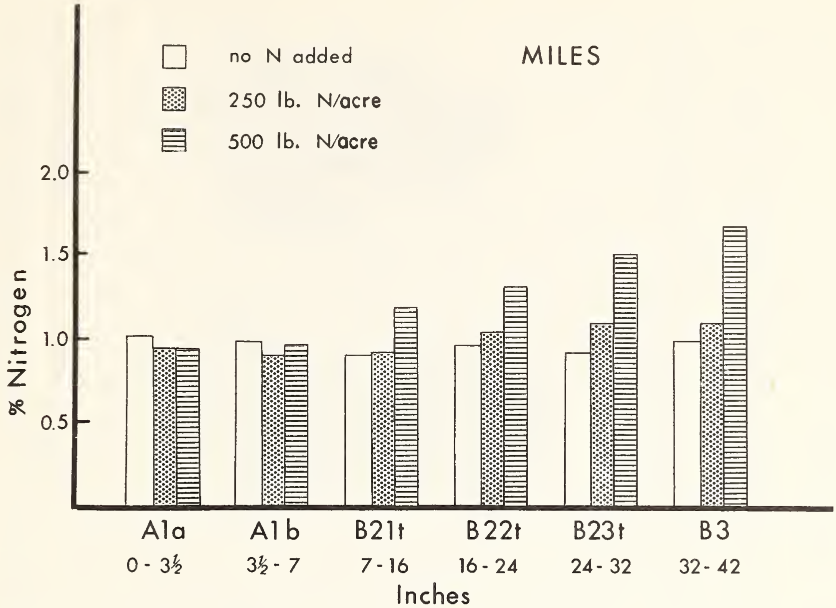

Figure 16. Effect of nitrogen rates on nitrogen content in millet tops grown on different horizons of Miles fine sandy loam.

Reinach Loam

Yield data for the Reinach loam are presented in figure 17. Results obtained on Reinach soil parallel those obtained on Amarillo, Miles, and Dalhart soils. On the N_2P_2 fertilizer treatment, all depth horizons produced equivalent yields; but, without fertilizer, the surface horizon outyielded the others.

Phosphorus rates used on Reinach soil (52 and 70 pounds of sodium bicarbonate-soluble phosphorus per acre) involved application of about 118 and 160 pounds of phosphorus per acre. Use of these rates resulted from a miscalculation. Intended rates were 26 and 35 pounds of sodium bicarbonate-soluble phosphorus per acre, one-half the rates used.

Nitrogen × phosphorus interactions were measured on soil from all depths except the 38- to 55-inch horizon. Nitrogen alone increased yield only on the surface soil, while phosphorus alone increased yield on 21- to 30- and the 38- to 55-inch horizons. Nitrogen and phosphorus in combination gave significant increases in yield on all depth horizons.

There were more differences in yield among the four nitrogen-phosphorus combination treatments on this soil type than on those

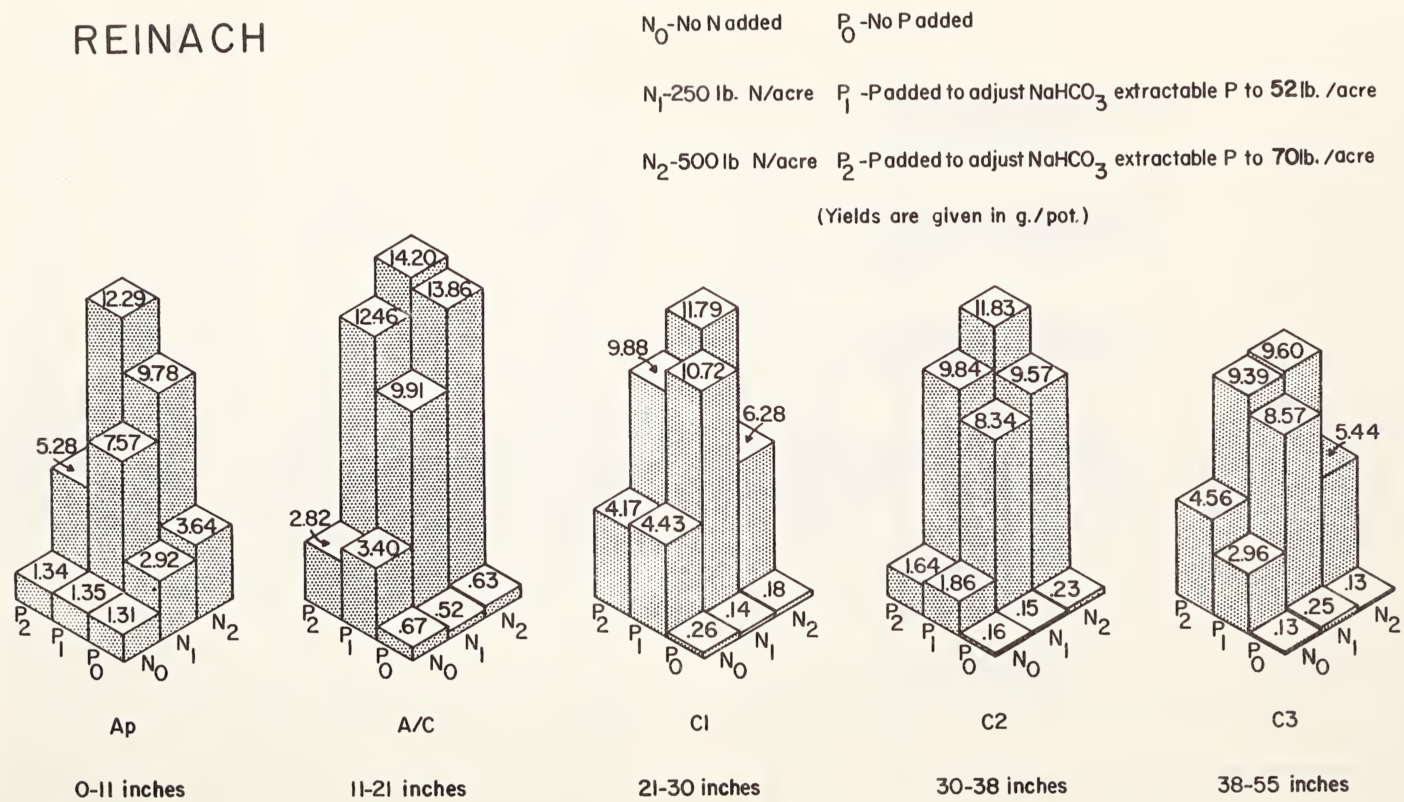

FIGURE 17.—Effect of fertilizer treatments on yields of millet produced on different horizons of Reinach loam.

previously discussed. Instances in which treatments including both nitrogen and phosphorus additions did not produce equivalent yields on like soil depths are as follows: (1) 0- to 11-inch depth: Each of the four produced different yields. Treatments ranked $N_1P_2 < N_1P_1 < N_2P_1 < N_2P_2$; (2) 11- to 21-inch depth: N_1P_1 yielded less than N_2P_1 and N_2P_2; (3) 21- to 30-inch depth: N_2P_1 yielded less than the other three treatments; (4) 30- to 38-inch depth: N_2P_2 outyielded N_1P_1; and (5) 38- to 55-inch depth: N_2P_1 yielded less than N_1P_2 and N_2P_2. It is interesting to note that the high phosphorus rate gave yield increases greater than the intermediate rate on three horizons even though the intermediate rate was higher than that ordinarily required for maximum yields on most soils (*15*).

Phosphorus content data are presented in figure 18. There was a trend towards increased phosphorus in the plant tissue with increasing increments of applied phosphorus on all horizons, but the trend was more marked on the 0- to 11- and 11- to 21-inch horizons. Applied nitrogen decreased phosphorus content on the 0- to 11- and 11- to 21-inch horizons. A similar effect was noted on the surface horizon of the Miles soil.

Nitrogen content of the plant tissue is presented in figure 19. The first increment of applied nitrogen (250 lb./acre) increased plant nitrogen content only on the 38- to 55-inch horizon, and the second increment (500 lb./acre) increased plant nitrogen content on all except the 21- to 30-inch horizon.

Dry matter yields and nitrogen and phosphorus analyses on the plant tissue show that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on soil from all depths. Productivities of the subsurface horizons were increased to levels equal to the level on the surface horizon.

Grant Silt Loam

Yield data for the Grant silt loam are presented in figure 20. With the N_2P_2 treatment, all soil depths produced statistically equivalent yields. Without fertilizer, yields on the surface horizon were higher than those on the subsurface horizons.

Nitrogen $\times$ phosphorus interaction effects were found only on the 0- to 5- and 22- to 48-inch depths. Nitrogen alone (N_2 rate) increased yield on the surface horizon but not on the other soil depths. Phosphorus alone increased yield on the 5- to 10-, 10- to 16-, 16- to 22-, and 22- to 48-inch depths. The combination of nitrogen and phosphorus increased yields on all depth horizons.

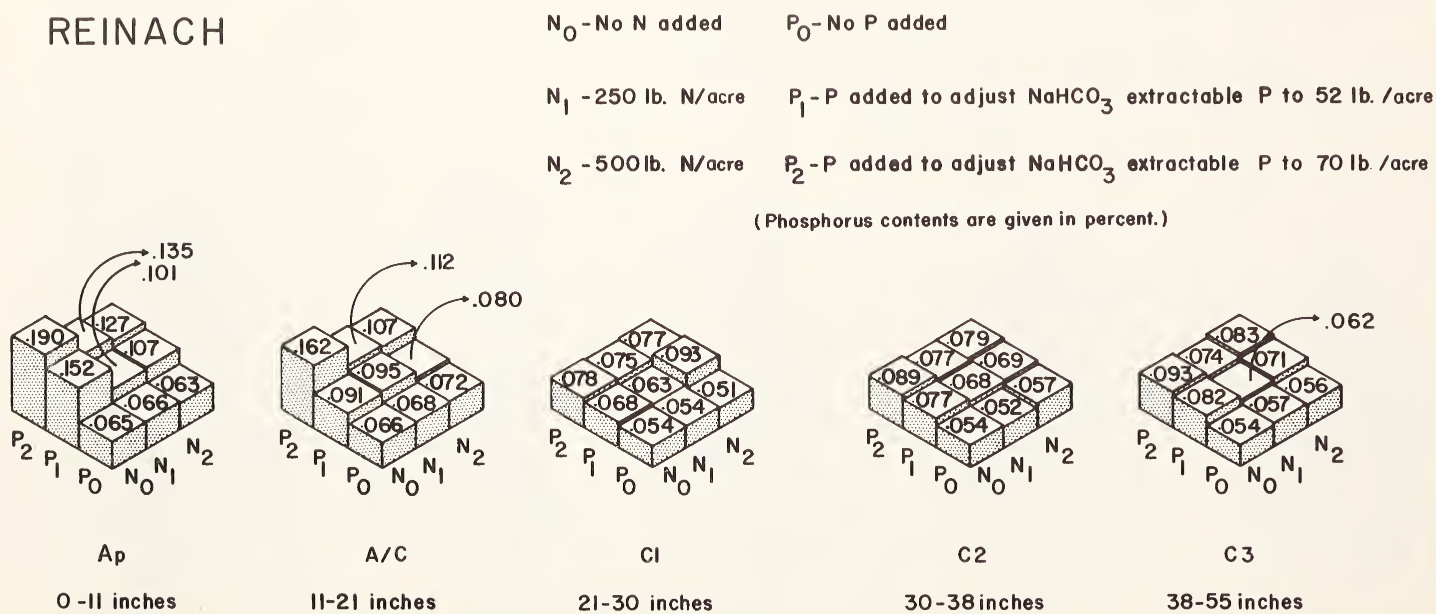

FIGURE 18.—Effect of fertilizer treatments on phosphorus content of millet tops grown on Reinach loam.

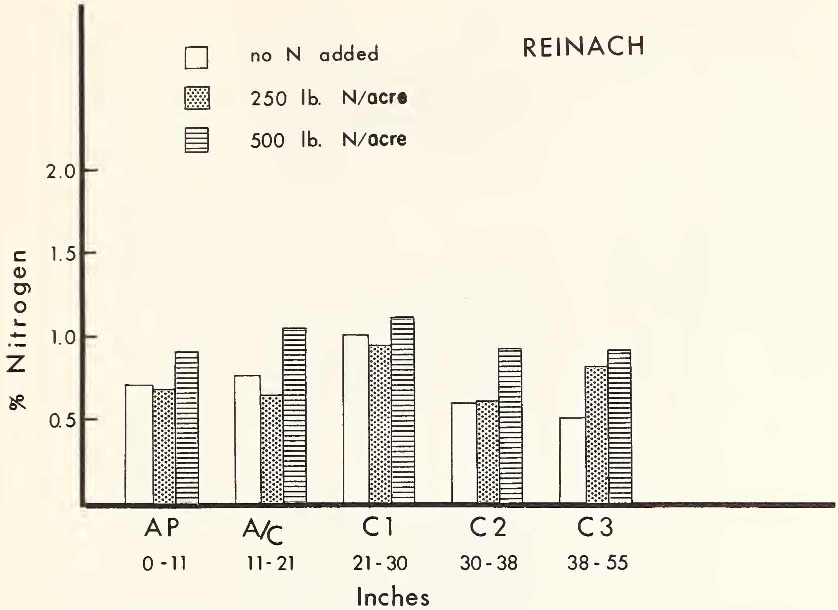

FIGURE 19.—Effect of nitrogen rates on nitrogen content in millet tops grown on different horizons of Reinach loam.

Within soil depths, the nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 0- to 5-inch depth: N_1P_1 outyielded N_1P_2; (2) 22- to 48-inch depth: N_1P_2 yielded less than N_1P_1 and N_2P_2; and (3) 48- to 54-inch depth: N_2P_2 outyielded N_1P_1 and N_2P_1. Phosphorus fertilization to 26 pounds of sodium bicarbonate-extractable phosphorus per acre (about 50 pounds of applied phosphorus per acre) was sufficient for maximum yields on all except the 48- to 54-inch depth. For some obscure reason, yields were much lower on treatments N_1P_1 and N_2P_1 on the 48- to 54-inch depth than on the other depth horizons.

Phosphorus content of the plant material (fig. 21) increased with increasing increments of applied phosphorus on all soil depths; however, phosphorus contents were higher on the 0- to 5- and 5- to 10-inch soil depths. This occurred even though all depth horizons were adjusted to equal sodium bicarbonate-soluble phosphorus contents.

Applied nitrogen increased nitrogen content of the plant tissue (fig. 22) on all depth horizons. Increases were greater on the deeper horizons than on horizons on or near the soil surface.

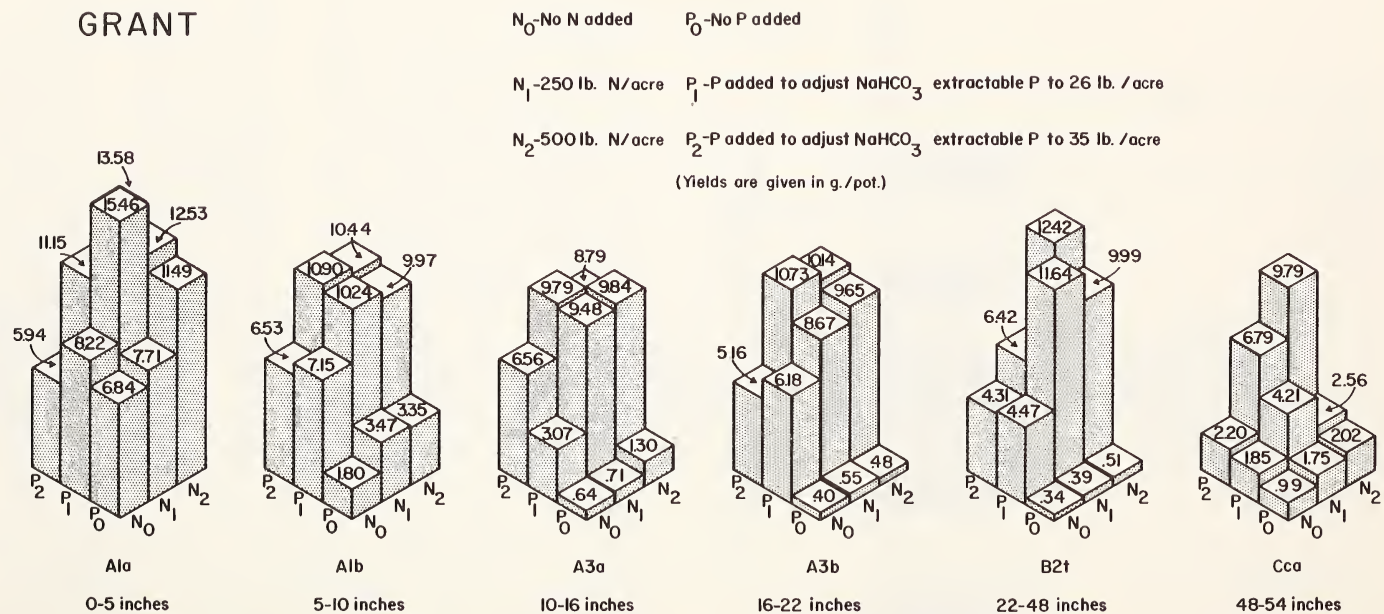

FIGURE 20.—Effect of fertilizer treatments on yields of millet produced on different horizons of Grant silt loam.

GRANT

N_0-No N added P_0-No P added

N_1-250 lb. N/acre P_1-P applied to adjust $NaHCO_3$ extractable P to 26 lb. /acre

N_2-500 lb. N/acre P_2-P applied to adjust $NaHCO_3$ extractable P to 35 lb. /acre

(Phosphorus contents are given in percent.)

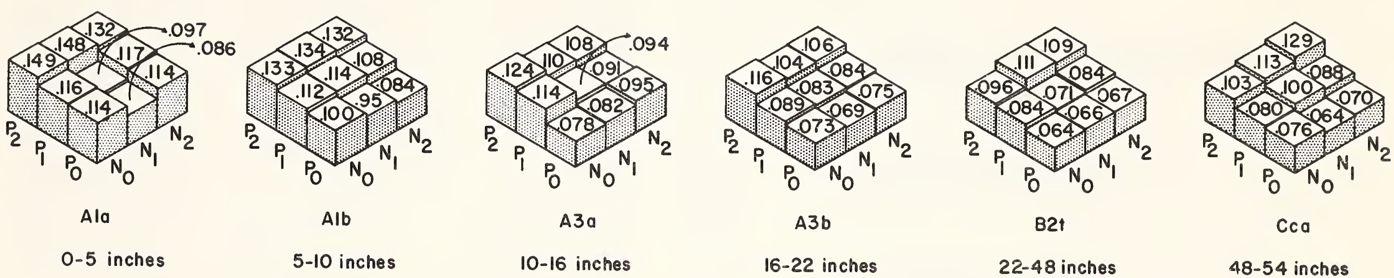

FIGURE 21.—Effect of fertilizer treatments on phosphorus content of millet tops grown on Grant silt loam.

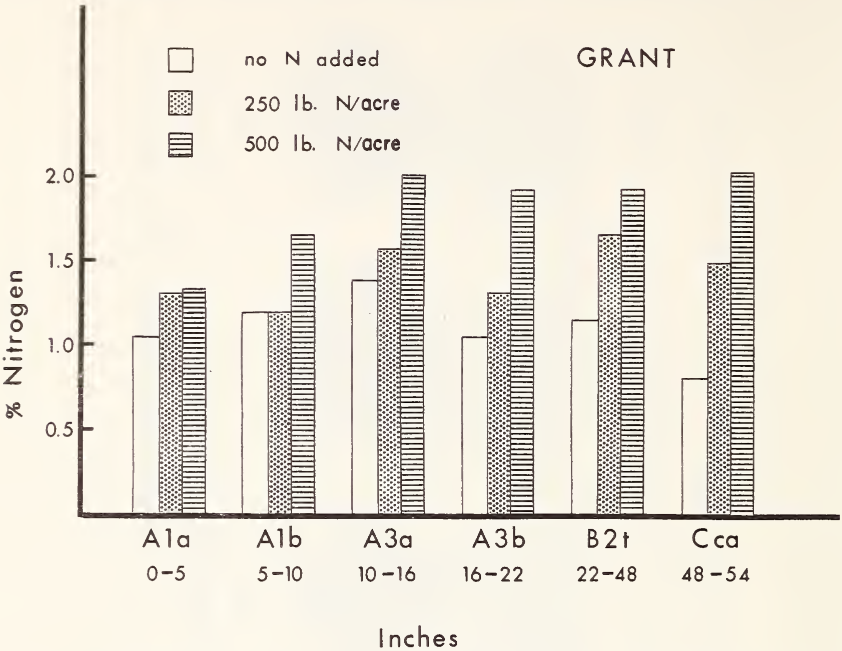

FIGURE 22.—Effect of nitrogen rates on nitrogen content in millet tops grown on different horizons of Grant silt loam.

Dry matter yields and nitrogen and phosphorus analyses on the plant tissue show that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on soil from all depths. Productivities of the subsurface horizons were increased to levels equal to the level on the surface horizon.

Abilene Silty Clay Loam

Yield data for the Abilene silty clay loam are presented in figure 23. Even though growth on Abilene soil was limited by low temperatures, the plants made sufficient growth for treatment differences to become obvious. On the N_2P_2 treatment, all soil depths produced like yields. Without fertilizer, the surface soil produced highest yields.

No nitrogen × phosphorus interactions were measured on any soil depth. Reduced growth with no response to nitrogen probably eliminated the interactions. Nitrogen alone did not increase yields on any soil depth, but phosphorus alone increased yields on all soil depths. The nitrogen-phosphorus combination gave yields higher than phosphorus alone only on the 0- to 7- and 40- to 50-

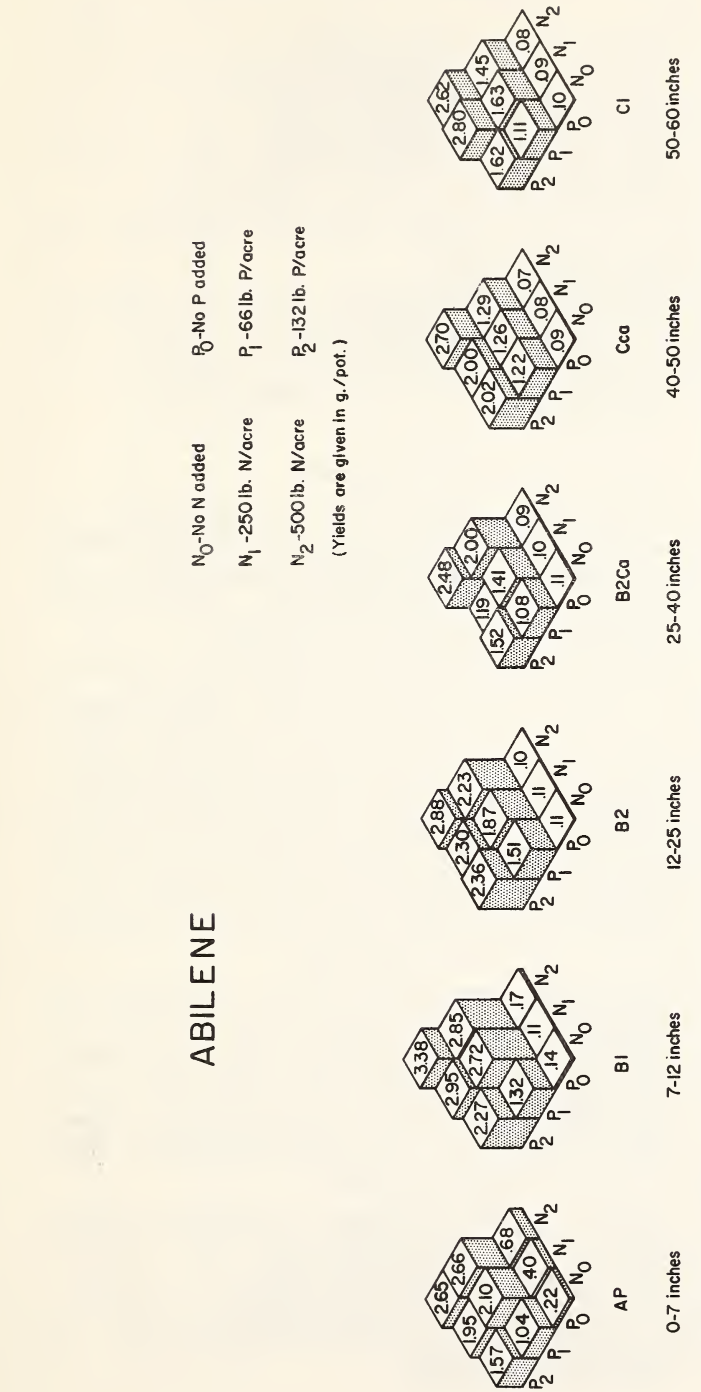

FIGURE 23.—Effect of fertilizer treatments on yields of millet produced on different horizons of Abilene silty clay loam.

inch depths. Within soil depths, the nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 12- to 25-inch depth: N_2P_2 outyielded N_1P_1; (2) 25- to 40-inch depth: N_2P_2 outyielded N_1P_1 and N_1P_2; (3) 40- to 50-inch depth: N_1P_1 and N_2P_1 yielded less than the other two, N_2P_2 outyielded all others; and (4) 50- to 60-inch depth: N_2P_1 yielded less than N_1P_2 and N_2P_2, N_1P_2 outyielded N_1P_1.

Nitrogen and phosphorus contents were not determined on plant tissue grown on Abilene soil.

Dry matter yields indicate that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on soil from all depths. Productivities of the subsurface horizons were increased to levels equal to the level of the surface horizon.

Spearville Silty Clay Loam

Yield data for the Spearville silty clay loam are presented in figure 24. Without fertilizer, soil from the two surface depths outyielded that from the other depths. With added fertilizer, soil from the surface and the 33½- to 40-inch depth yielded significantly more than all except the 17½- to 26-inch depth.

Nitrogen × phosphorus interactions were observed on soil from all depths except 0- to 4½ and 4½- to 7½ inches. Nitrogen alone increased yields only on soil from the 0- to 4½- and 4½- to 7½-inch depths. Phosphorus alone increased yields on soil from all except the 4½- to 7½-inch depth. Nitrogen and phosphorus in combination increased yields on all soil depths. Within soil depths, the nitrogen-phosphorus combination treatments produced equivalent yields except in the following instances: (1) 0- to 4½-inch depth: N_1P_2 yielded less than N_2P_1 and N_2P_2; and (2) 7½- to 17½-inch depth: N_2P_2 yielded less than N_1P_1 and N_2P_1.

The phosphorus content of the plant (fig. 25) increased with increasing increments of applied phosphorus on soil horizons below 7½ inches. On the 0- to 4½- and 4½- to 7½-inch horizons where native sodium bicarbonate-extractable phosphorus levels were relatively high, plant phosphorus contents were higher, and the small amounts of applied phosphorus had little effect on the phosphorus content of the plant tissue.

The nitrogen content of the plant tissue is presented in figure 26. On all horizons except the 7½- to 17½-inch depth, the first increment of applied nitrogen decreased nitrogen content of the plant tissue, whereas nitrogen contents with the high rate were either not significantly different from or less than the contents obtained with no nitrogen added.

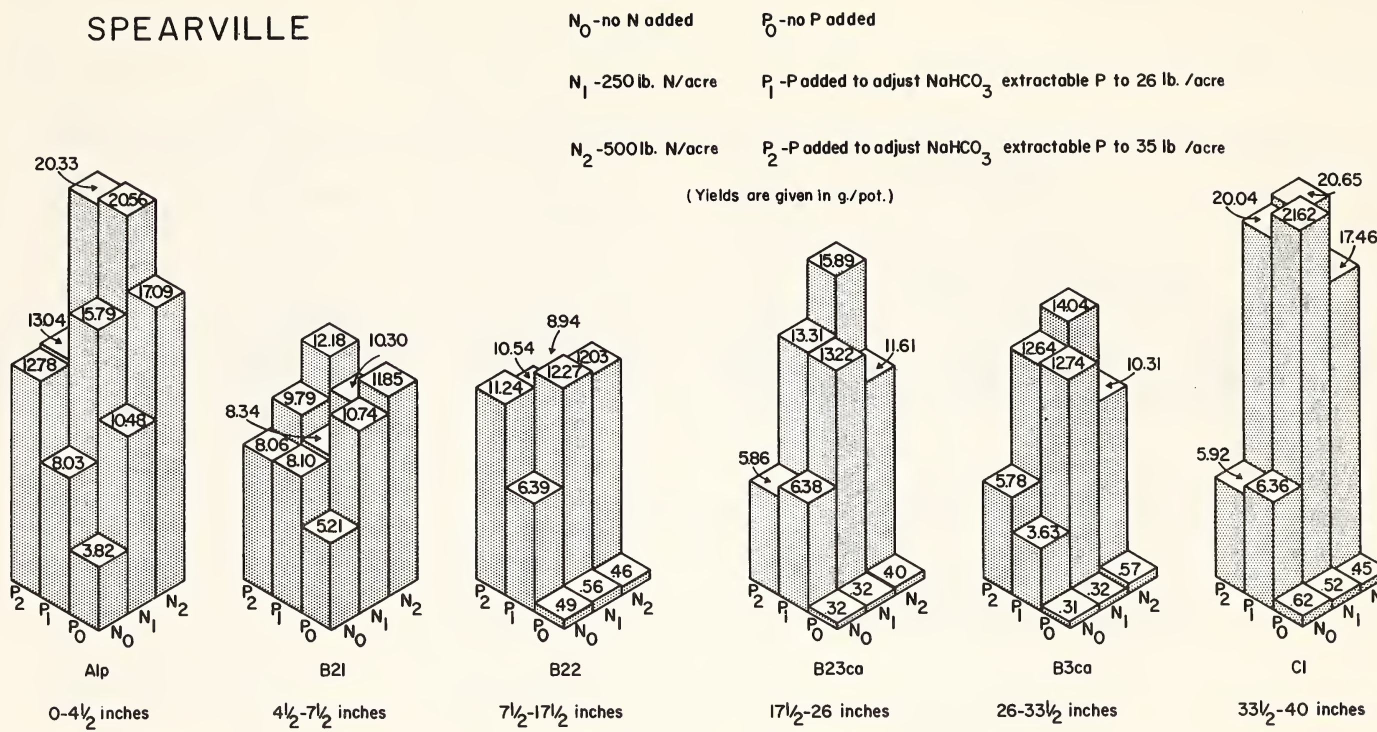

FIGURE 24.—Effect of fertilizer treatments on yields of millet produced on different horizons of Spearville silty clay loam.

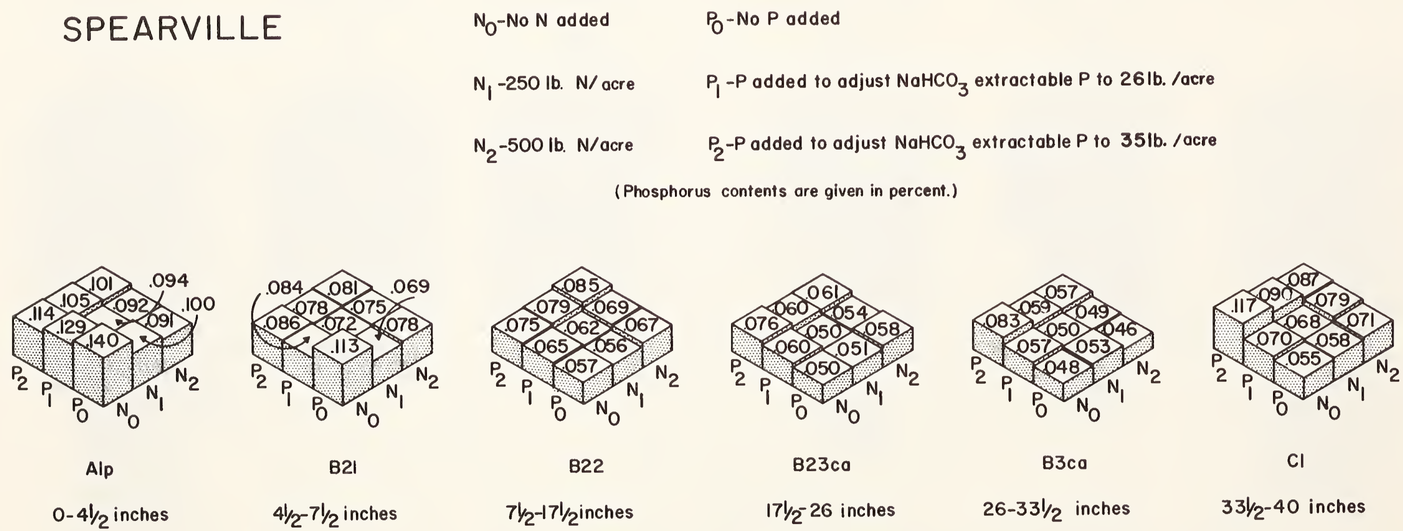

FIGURE 25.—Effect of fertilizer treatments on phosphorus content of millet tops grown on Spearville silty clay loam.

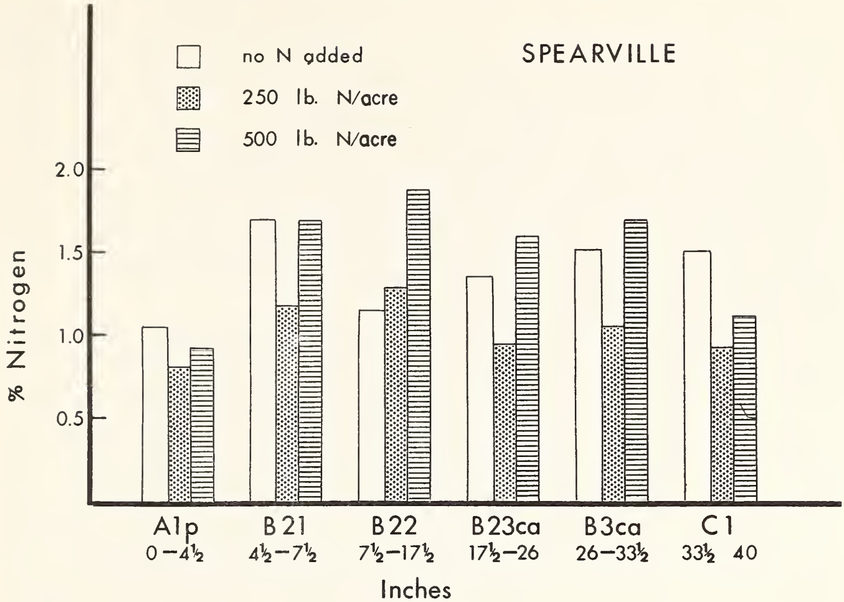

FIGURE 26.—Effect of nitrogen rates on nitrogen content on millet tops grown on different horizons of Spearville silty clay loam.

Dry matter yields and nitrogen and phosphorus analyses on the plant tissue show that the N_2P_2 treatment contained sufficient nitrogen and phosphorus for maximum yields on soil from all depths. Productivities of soil from the 17½- to 26- and 33½- to 40-inch depths were brought to levels equal to the level on the surface horizon. Productivities of the remaining horizons were increased to levels approaching that of the surface.

DISCUSSION

The soil types studied are representative of the arable soils of the Southern Great Plains. They differ in texture and parent material, but all occur on unconsolidated parent materials that are aeolian or alluvial in origin. Results obtained on the various soils are strikingly similar. Without fertilizer, yields on subsurface horizons were inferior to those on topsoils; but with nitrogen and phosphorus, yield levels were almost as high, as high, or in some cases higher on subsurface horizons than on surface horizons.

On the sandier soils (Amarillo, Dalhart, and Miles) that contained horizons of finer textured materials, the finer textured layers were brought to higher levels of productivity than the surface soils. Most of the available phosphorus was in the topsoil or in the topsoil and the layer immediately below it. Available nitrogen was more plentiful in the surface horizons than in the deeper ones but was distributed deeper in the profile than phosphorus. Thus, nitrogen was more limiting than phosphorus in the surface layers, and phosphorus was more limiting than nitrogen in the deeper horizons.

In this greenhouse study, plant yield and nitrogen- and phosphorus-content data show that the N_2P_2 treatments were adequate for the production of maximum yields. Fertilizer requirements for maximum yields in the field are lower than those for maximum yields in the greenhouse; thus, rate information from this study is not directly applicable to the field. However, in a field study on Pullman soil (*6*), maximum grain sorghum yields were obtained with 200 pounds of available nitrogen per acre (soil nitrate nitrogen plus applied nitrogen) and phosphorus fertilization to a level of 35 pounds of sodium bicarbonate-soluble phosphorus per acre. For maximum yields, more nitrogen and phosphorus were required on subsoils than on topsoils. This requirement, apparent in both field and greenhouse studies, is explained by the fact that most of the soil organic matter is in the topsoil.

The amount of phosphorus required to establish desired sodium bicarbonate-soluble phosphorus levels can be calculated by dividing the desired amount of increase in sodium bicarbonate-soluble phosphorus by the appropriate regression coefficients from figures 1 through 7. Olsen and others (*15*) reported that 22 pounds of sodium bicarbonate-soluble phosphorus is adequate for most crops. That rate was sufficient for maximum yields of grain sorghum in all but one instance in the field study on Pullman soil.

The effect of topsoil removal on crop yields is dependent upon the physical as well as the chemical properties of individual soil profiles. Since the experiments reported here were conducted in the greenhouse on disturbed soil, effects of physical conditions could not be assessed. Other research, however, has shown that physical conditions of similar subsoils have not been detrimental to plant growth. Gingrich and Oswalt (*7*) obtained satisfactory yields of cotton on Reinach soil that had from 0.8 to 1.3 feet of topsoil removed. Also, Eck, Hauser, and

Ford (*6*) obtained satisfactory yields of grain sorghum on Pullman subsoil.

Topsoil removal necessitates changes in soil management practices. Subsoils are frequently finer textured, and after land forming the resulting clay soil may have to be managed differently than the original loam. Changed surface textures may change water intake characteristics and moisture storage relations. Generally, infiltration will be slowed and runoff increased. The fine-textured materials have higher water-holding capacities; thus, more available water will be stored near the surface where it is susceptible to evaporation. Under all circumstances, the effects of topsoil loss should be determined before topsoil is removed from productive lands.

Results of this study show that the subsurface soil horizons can be as productive as the topsoil. Fertilizer can be used to compensate for the loss of topsoil. Thus, if fertilizer is applied and if adequate soil depth remains, deep cuts may be made on these soils without impairing yield potentials. The yields obtained on the mixture of horizons of Dalhart soil show that mixing some surface soil with the subsoil may enhance productivity. This suggests that some surface soil should be added to the subsoil during the land-forming or earth-moving operations. These data also indicate that deep plowing to bring finer textured soil material to the surface for control of wind erosion may not be detrimental to productivity. With a conscientious management program, surface soil removal will not impair sustained high levels of production on the seven soils examined in this study.

SUMMARY

Profiles of Amarillo fine sandy loam, Miles fine sandy loam, Dalhart fine sandy loam, Reinach loam, Grant silt loam, Abilene silty clay loam, and Spearville silty clay loam were studied in greenhouse and laboratory experiments at the Southwestern Great Plains Research Center, Bushland, Tex. Individual genetic horizons of each profile were studied under nine fertilizer treatments consisting of a complete factorial of three rates of nitrogen and three rates of phosphorus. German millet was grown as a test crop. Supporting laboratory research consisted of determination of phosphorus retention curves of the soils, physical and chemical properties of the soils, and nitrogen and phosphorus contents of the plant tissue.

Without fertilizer, yields on subsurface horizons were inferior to those on topsoils; but with nitrogen and phosphorus, yield levels were almost as high, as high, or in some cases higher on subsurface horizons than on surface horizons. Yields and nitrogen and phosphorus analyses on the plant tissue indicated that the nitrogen and phosphorus rates used were adequate for maximum yields in the greenhouse studies. Because fertilizer requirements in the field are lower than those in the greenhouse, rate information from this study is not directly applicable to field conditions. In a field study on Pullman soil (*6*), however, maximum grain sorghum yields were obtained with fertilization to levels of 200 pounds of available nitrogen per acre and 35 pounds of sodium bicarbonate-soluble phosphorus per acre. Phosphorus retention curves presented here may be used in determining phosphorus rates required to adjust sodium bicarbonate-soluble phosphorus levels.

Topsoil should not be removed from productive lands until effects of topsoil loss are determined; however, results obtained in these studies indicate that if a conscientious soil management program is followed, surface soil removal will not impair sustained high levels of production on the seven soils examined in this study.

LITERATURE CITED

(1) Black, A. L., and Whitney, R. S.
1966. PHOSPHORUS STATUS OF HORIZONS OF FOUR BENCHMARK LOESSIAL SOILS OF THE CENTRAL GREAT PLAINS REGION. Soil Sci. Soc. Amer. Proc. 30: 359–362.

(2) Carlson, C. W., and Grunes, D. L.
1958. EFFECT OF FERTILIZATION ON YIELDS AND NUTRIENT CONTENT OF BARLEY. Soil Sci. Soc. Amer. Proc. 22: 140–145.

(3) ——— Grunes, D. L., Alessi, J., and Reichman, G. A.
1961. CORN GROWTH ON GARDENA SURFACE AND SUBSOIL AS AFFECTED BY APPLICATIONS OF FERTILIZER AND MANURE. Soil Sci. Soc. Amer. Proc. 25: 44–47.

(4) Duncan, D. B.
1955. MULTIPLE RANGE AND MULTIPLE F TESTS. Biometrics 11: 1–42.

(5) Eck, H. V., and Ford, Robert H.
1962. RESTORING PRODUCTIVITY ON EXPOSED SUBSOILS. Jour. Soil and Water Conserv. 17: 274–275.

(6) ——— Hauser, V. L., and Ford, R. H.
1965. FERTILIZER NEEDS FOR RESTORING PRODUCTIVITY OF PULLMAN SILTY CLAY LOAM AFTER VARIOUS DEGREES OF SOIL REMOVAL. Soil Sci. Soc. Amer. Proc. 29: 209–213.

(7) Gingrich, J. R., and Oswalt, E. S.
1965. SOIL MANAGEMENT PRACTICES FOR COTTON PRODUCTION ON LEVELED IRRIGATION LAND. Okla. Agr. Expt. Sta. Bul. B–636, 15 pp.

(8) Grunes, D. L., Boawn, L. C., Carlson, C. W., and Viets, F. G., Jr.
1961. ZINC DEFICIENCY OF CORN AND POTATOES AS RELATED TO SOIL AND PLANT ANALYSIS. Agron. Jour. 53: 68–71.

(9) Hayes, O. E., Bay, C. E., and Hull, H. H.
1948. INCREASING PRODUCTION ON AN ERODED LOESS-DERIVED SOIL. Jour. Amer. Soc. Agron. 41: 1061–1069.

(10) Heilman, Marvin D., and Thomas, James R.
1961. LAND LEVELING CAN ADVERSELY AFFECT SOIL FERTILITY. Jour. Soil Water Conserv. 16: 71–72.

(11) Jackson, M. L.
1958. SOIL CHEMICAL ANALYSIS. Prentice-Hall, Inc., Englewood Cliffs, N.J. 498 pp.

(12) Latham, E. E.
1940. RELATIVE PRODUCTIVITY OF THE A HORIZON OF THE CECIL SANDY LOAM AND THE B AND C HORIZONS EXPOSED BY EROSION. Jour. Amer. Soc. Agron. 32: 950–954.

(13) Mathers, A. C., Gardner, H. R., Lotspeich, F. B., Taylor, H. M., Laase, G. R., and Daniell, R. E.
1963. SOME MORPHOLOGICAL, PHYSICAL, CHEMICAL, AND MINERALOGICAL PROPERITIES OF SEVEN SOUTHERN GREAT PLAINS SOILS. U.S. Dept. Agr., ARS 41–85, 63 pp.

(14) Nelson, J. L., and Crawford, C. L.
1960. FERTILIZER NEEDS OF LEVELED LANDS OF THE COLUMBIA BASIN. Wash. Agr. Expt. Sta. Cir. 368, 4 pp.

(15) Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A.
1954. ESTIMATION OF AVAILABLE PHOSPHORUS IN SOILS BY EXTRACTION WITH SODIUM BICARBONATE. U.S. Dept. Agr. Cir. 939, 19 pp.

(16) Reuss, J. O., and Campbell, R. E.
1961. RESTORING PRODUCTIVITY TO LEVELED LAND. Soil Sci. Soc. Amer. Proc. 25: 302–304.

(17) Rost, C. O.
1940. THE RELATIVE PRODUCTIVITY OF HUMID SUBSOILS. Soil Sci. Soc. Amer. Proc. 4: 281–287.

(18) Smith, R. M., and Pohlman, G. G.
1951. A COMPARISON OF THE SUBSOILS AND SURFACE SOILS IN THE GREENHOUSE AS AN AID TO UNDERSTANDING AND RECLAIMING ERODED SOILS. Agron. Jour. 43: 259–264.

(19) Snedecor, G. W.
1956. STATISTICAL METHODS. Iowa State College Press, Ames, Iowa. Ed. 5, Chapt. 11, 12, 534 pp.

(20) Whitney, R. S., Gardner, Robert, and Robertson, D. W.
1950. THE EFFECTIVENESS OF MANURE AND COMMERCIAL FERTILIZER IN RESTORING THE PRODUCTIVITY OF SUBSOILS EXPOSED BY LEVELING. Agron. Jour. 42: 239–245.

APPENDIX

Table 2.—*Description of an Amarillo fine sandy loam profile*

Location: 300 feet east and 100 feet north of SW. cor. sec. 28, Sabine County School Land, Hale County, Tex.

Soil horizon	Depth	Description
	Inches	
A1	0–6	Dark-brown (7.5YR 3/2, moist) fine sandy loam; weak granular structure; very friable when moist; noncalcareous; upper 1 to 2 inches is from recent wind deposition.
B21t	6–19	Dark reddish-brown (5YR 3/4, moist) sandy clay loam; moderate, very coarse prismatic and weak, fine, subangular blocky structure; very hard when dry; friable when moist; noncalcareous.
B22t	19–40	Yellowish-red (5YR 3/6, moist) sandy clay loam; similar structure, consistence, and reaction as above.
B23t	40–54	Yellowish-red (5YR 4/6, moist) sandy clay loam; similar structure, consistence, and reaction as above.
Cca1	54–75	Yellowish-red (5YR 4/6, moist) sandy clay loam; weak, fine, subangular blocky structure; slightly hard when dry; friable when moist; many films and threads of $CaCO_3$; many $CaCO_3$ concretions mostly ½ to 2 inches in diameter; calcareous.
Cca2	75–100	Yellowish-red (5YR 5/6, moist) fine sandy loam; similar structure and consistence as above; many films and threads of $CaCO_3$; many $CaCO_3$ concretions up to 2 inches in diameter; calcareous.
C	100–120	Similar to horizon above, but $CaCO_3$ decreases with depth.

Table 3.—*Some physical properties of an Amarillo fine sandy loam profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–1	A1a	67.8	14.2	18.0	Fine sandy loam	9.6	4.1
1–3	A1b	80.0	7.2	12.8	------do------	13.7	6.7
3–6	A1c	73.8	6.2	20.0	------do------	13.7	6.7
6–19	B21t	67.3	6.5	26.2	Sandy clay loam	17.4	9.5
19–30	B22ta	70.1	9.1	20.8	------do------	15.4	7.2
30–40	B22tb	70.8	8.6	20.6	------do------	15.4	7.2
40–54	B23t	71.7	6.3	22.0	------do------	11.9	5.4

[1] Particle size distribution by pipette method.

[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 4.—*Some chemical properties of an Amarillo fine sandy loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–3	A1a	3.7	213	0.073	6.1	0.89	350
3–7	A1b	3.3	232	.066	5.9	.87	225
7–14	B21ta	2.2	223	.076	6.0	.97	265
14–20	B21tb	1.1	232	.058	6.0	.84	275
20–30	B22ta	1.1	172	.033	6.3	.35	215
30–40	B22tb	1.8	173	.029	6.3	.27	225

TABLE 5.—*Description of a Dalhart fine sandy loam profile*

Location: 75 feet east and 200 feet north of SW. cor. of SE¼ sec. 34, T. 4 N., R. 4 E. of the 100 meridian, Cimarron County, Okla.

Soil horizon	Depth	Description
	Inches	
A1p	0–4	Dark-brown to brown (10YR 4/3, moist) loamy fine sand (or winnowed fine sandy loam); single grain structure; soft when dry; very friable when moist; noncalcareous to slightly calcareous.
A12	4–8	Same color and characteristics as A1p except the texture, which is fine sandy loam.
B21	8–13	Brown (10YR 4/3, moist) sandy clay loam; very coarse compound structure breaking to weak to moderate, fine subangular blocky structure; hard when dry; friable when moist; slightly calcareous.
B22	13–23	Brown to dark yellowish-brown (10YR 4/4, moist) sandy clay loam; weak coarse prismatic breaking to strong to moderate rounded, fine subangular blocky structure; friable when moist; hard when dry; slightly calcareous.
B31ca	23–26	Light yellowish-brown (9YR 5/4, moist) sandy clay loam; compound, weak, very coarse prismatic structure; slightly hard when dry; friable when moist; fine and medium $CaCO_3$ concretions; calcareous.
B32ca	36–53	A gradual transitional area, in texture and color; at 44 inches, light yellowish-brown (9YR 5/4, moist) loam; rounded weak to moderate, medium and fine subangular blocky structure; friable when moist; hard when dry; calcareous.
C	53–68	Reddish-yellow (7.5YR 4/6, moist) heavy fine sandy loam becoming more sandy with depth; friable; calcareous.

TABLE 6.—*Some physical properties of a Dalhart fine sandy loam profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		1/3 atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–4	A1p	84	4	12	Loamy sand	4.15	2.31
4–8	A12	76	10	14	Sandy loam	6.48	3.83
8–13	B21	46	22	32	Sandy clay loam	19.66	12.00
13–23	B22	40	24	36	Clay loam	20.69	12.45
23–36	B31ca	44	26	30	______do_____	15.33	8.57

[1] Particle size distribution by Bouyoucos method.
[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 7.—*Some chemical properties of a Dalhart fine sandy loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–4	A1p	9.0	72	0.024	7.5	0.46	190
4–8	A12	2.9	97	.032	7.3	.49	160
8–13	B21	.7	318	.074	6.0	.84	265
13–23	B22	.4	316	.065	6.5	.65	275
23–36	B31ca	.1	290	.036	7.9	.30	225
36–54	B32ca	--	--	.031	7.9	.16	290

TABLE 8.—*Description of a Miles fine sandy loam profile*

Location: 0.6 mile north, 0.1 mile east, and 100 feet north of SW. cor. sec. 4, block L, Gunter Munson survey, Hall County, Tex.

Soil horizon	Depth	Description
	Inches	
A1	0–6	Dark-brown (7.5YR 3/2, moist) fine sandy loam; weak granular structure; soft when dry; very friable when moist; noncalcareuos.
B21t	6–16	Dark-brown (7.5YR 2/2, moist) sandy clay loam; moderate, very coarse prismatic and weak, fine, subangular blocky structure; very hard when dry; friable when moist; noncalcareous.
B22t	16–23	Dark reddish-brown (5YR 3/3, moist) sandy clay loam; similar structure, consistence, and reaction as above.
B23t	23–32	Dark reddish-brown (5YR 3/4, moist) sandy clay loam; similar structure, consistence, and reaction as above.
B3	32–50	Yellowish-red (5YR 3/6, moist) fine sandy loam; weak, fine, subangular blocky structure; hard when dry; friable when moist; noncalcareous.
Cca	50–62	Yellowish-red (5YR 4/6, moist) fine sandy loam; many threads and films of $CaCO_3$; calcareous.

TABLE 9.—*Some physical properties of a Miles fine sandy loam profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–6	A1	75.1	13.4	11.5	Fine sandy loam	13.0	4.8
6–23	B21, B22t	67.5	10.2	22.3	Sandy clay loam	18.2	8.8
23–32	B23t	63.1	10.4	26.5	______do______	20.1	9.8
32–50	B3	72.6	8.5	18.9	Fine sandy loam	16.2	7.7
50–62	Cca	79.0	5.7	15.3	______do______	12.8	6.2
62–75		82.4	5.1	12.5	______do______	10.5	5.0

[1] Particle size distribution by pipette method.

[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 10.—*Some chemical properties of a Miles fine sandy loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–3½	A1a	14.8	270	0.069	7.1	1.16	300
3½–7	A1b	4.1	161	.069	7.1	.81	280
7–16	B21t	4.1	244	.069	6.7	.76	255
16–24	B22t	2.6	270	.064	6.7	.92	275
24–32	B23t	3.3	238	.056	6.5	.78	255
32–42	B3	2.0	167	.031	6.5	.40	180

TABLE 11.—*Description of a Reinach loam profile*

Location: 321 feet west and 19 feet south of SW. cor. of weather yard on east end of the Cotton Research Station, Chickasha, Okla.

Soil horizon	Depth	Description
	Inches	
Ap	0–11	Mixture of materials, about 50–50 of dark-brown (7.5YR 3/2, moist) and reddish-brown (5YR 3/3, moist) very fine granular; friable when moist; slightly hard when dry; pH 7.5.
A/C	11–21	Reddish-brown (4YR 3/4, moist) loam; weak to moderate medium and fine granular; friable when moist; slightly hard when dry; pH 7.0.
C1	21–30	Reddish-yellow (5YR 5/4, moist) to yellowish-red (5YR 3/6, moist) silty clay loam; weak, coarse and medium granular; friable when moist; slightly hard when dry; pH 8.0.
C2	30–38	Yellowish-red (3YR 3/4, moist) silt loam; weak to moderate, coarse and medium granular; friable when moist; pH 8.05.
C3	38–55	Yellowish-red (5YR 4/6, moist) loam; structureless to weak granular; friable when moist; loose when dry; pH 8.15; was examined to 109 inches and was similar to this horizon.

TABLE 12.—*Some physical properties of a Reinach loam profile*

Depth increments (inches)	horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–11	Ap	33.6	48.0	18.4	Loam	16.49	5.75
11–21	A/C	31.6	45.5	22.9	------do------	18.89	6.93
21–30	C1	11.2	60.4	28.4	Silty clay loam	23.07	8.04
30–38	C2	19.1	58.5	22.4	Silt loam	19.31	6.29
38–55	C3	42.0	43.7	14.3	Loam	11.72	3.97

[1] Particle size distribution by Bouyoucos method.
[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 13.—*Some chemical properties of a Reinach loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–11	Ap	3.6	345	0.047	7.2	1.05	118
11–21	A/C	2.6	423	.048	7.1	.72	89
21–30	C1	.1	601	.066	7.8	.72	139
30–38	C2	.1	606	.037	7.7	.61	74
38–55	C3	0	417	.018	7.9	.40	52

TABLE 14.—*Description of a Grant silt loam profile*

Location: 735 feet east and 840 feet north of SW. cor. NW¼ sec. 22, T. 26 N., R. 11 W., Alfalfa County, Okla.

Soil horizon	Depth	Description
	Inches	
A1	0–10	Dark-brown (7.5YR 4/4, moist) silt loam; weak granular structure; hard when dry; friable when moist; noncalcareous.
A3	10–22	Dark reddish-brown (5YR 3/4, moist) silt loam; moderate, medium, granular structure; hard when dry; friable when moist; noncalcareous.
B2t	22–48	Yellowish-red (5YR 4/8, moist) loam; moderate, medium, subangular blocky and granular structure; friable when moist; some waterworn gravel; noncalcareous.

TABLE 14.—*Description of a Grant silt loam profile*

Location: 735 feet east and 840 feet north of SW. cor. NW¼ sec. 22, T. 26 N., R. 11 W., Alfalfa County, Okla.

Soil horizon	Depth	Description
	Inches	
Cca	48–54	Yellowish-red (5YR 4/6) silt loam; weak granular structure; hard when dry; friable when moist; calcareous.
C	54–72	Yellowish-red (5YR 4/6) silt loam; weak granular structure; friable when moist; calcareous; grades to gravel bed.
IIC	72+	Sand and gravel bed.

TABLE 15.—*Some physical properties of a Grant silt loam profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–5	A1a	25.1	65.4	9.5	Silt loam	16.8	4.8
5–10	A1b	25.1	65.4	9.5	______do______	16.8	4.8
10–16	A3	26.0	61.1	12.0	______do______	14.4	5.2
16–22	A3b	26.9	61.1	12.0	______do______	14.4	5.2
22–48	B2t	50.3	36.8	12.9	Loam	14.9	5.6
48–54	Cca	45.7	51.4	2.9	Silt loam	24.9	8.6
54–68	C	32.1	66.3	1.6	______do______	14.5	3.8

[1] Particle size distribution by pipette method.
[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 16.—*Some chemical properties of a Grant silt loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchangeable K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–5	A1a	5.7	361	0.141	6.5	2.86	415
5–10	A1b	1.1	290	.086	6.6	1.83	332
10–16	A3a	.4	242	.066	6.4	1.45	284
16–22	A3a	.4	204	.055	6.5	1.27	269
22–48	B2t	1.1	218	.042	6.3	1.03	173
48–54	Cca	7.2	223	.038	6.5	.82	194
54–72	C	11.4	223	.042	6.4	.72	200

TABLE 17.—*Description of an Abilene silty clay loam profile*

Location: 2.7 miles north of county courthouse, Vernon, Tex. (U.S. Highway 283), 0.6 mile west, 0.4 mile north (farm road 925), 0.3 mile north (rural road), and 150 feet west of road in cultivated field

Soil horizon	Depth	Description
	Inches	
Ap	0–7	Brown (10YR 3/2, moist) silty clay loam; weak, very fine, subangular blocky structure; slightly hard dry; friable moist; noncalcareous.
B1	7–12	Dark-brown (7.5YR 3/2, moist) silty clay loam; moderate fine subangular blocky structure; hard dry; friable moist; noncalcareous.
B2	12–25	Dark-brown (7.5YR 3/2, moist) silty clay; moderate medium blocky structure; very hard dry; firm moist; plastic wet; noncalcareous in upper part, calcareous below 20 inches.
B2ca	25–40	Brown (7.5YR 4/2, moist) silty clay; moderate medium blocky structure; very hard dry; firm moist; plastic wet; contains 3 to 5 percent, by volume, of small soft spots of $CaCO_3$; calcareous.
Cca	40–50	Brown (7.5YR 4/3, moist) silty clay; weak blocky structure; very hard dry; firm moist; contains 7 to 10 percent, by volume, of $CaCO_3$; calcareous.
C1	50–60	Brown (7.5YR 4/3, moist) silty clay; weak subangular blocky structure; calcareous.
C2	60–74+	Yellowish-red (5YR 4/6, moist) silty clay; weak subangular blocky structure; calcareous.

TABLE 18.—*Some physical properties of an Abilene soil profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–7	Ap	17.6	53.0	29.4	Silty clay loam	27.62	9.83
7–12	B1	17.6	44.0	38.4	______do______	28.82	13.78
12–25	B2	15.6	42.8	41.6	Silty clay	29.26	14.42
25–40	B2ca	15.2	40.0	44.8	______do______	28.80	14.21
40–50	Cca	12.4	43.2	44.4	______do______	29.13	14.34
50–60	C1	12.4	41.2	46.4	______do______	30.78	15.21
60+	C2	14.4	32.0	53.6	Clay		

[1] Particle size distribution by Bouyoucos method.

[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 19.—*Some chemical properties of an Abilene silty clay loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–7	Ap	3.7	391	0.070	7.4	1.41	353
7–12	B1	2.0	386	.064	7.6	1.29	300
12–25	B2	2.4	401	.045	7.5	.94	272
25–40	B2ca	2.6	350	.032	7.9	.61	263
40–50	Cca	1.7	391	.025	8.0	.52	273
50–60	C1	1.1	374	.025	8.1	.46	294

TABLE 20.—*Description of a Spearville silty clay loam profile*

Location: 1,980 feet west and 1,600 feet south of E¼ cor. sec. 8, T. 14 S., R. 18 W., Ellis County, Gans. (Adjacent to Conservation Benching Experiment, Fort Hays Experiment Sta., Hays, Kans.)

Soil Horizon	Depth	Description
	Inches	
A1p	0–4½	Black (10YR 2/1.5, moist) silty clay loam; weak to moderate fine granular structure; firm moist; hard dry; noncalcareous.
B21	4½–7½	Very dark-brown (10YR 2/2, moist) silty clay; moderate fine and medium irregular angular blocky structure; very firm moist; very hard dry; noncalcareous.
B22	7½–17½	Very dark-brown (10YR 2.5/2, moist) clay; moderate fine and medium subangular and angular blocky structure; noncalcareous.
B23ca	17½–26	Very dark-gray (10YR 3/1.5, moist) clay; moderate medium angular and subangular blocky structure; very firm moist; very hard dry; weak to strongly calcareous with depth.
B3ca	26–33½	Gray (10YR 4/1.5, moist) silty clay; weak to moderate medium angular blocky structure; very firm moist; very hard dry; strongly calcareous.
C1	33½–40	Dark-gray (10YR 4/1.5, moist) silty clay; weak, coarse prismatic structure breaking to weak, medium blocky structure; firm moist; hard dry; calcareous.
A1b	40–50	Dark-gray 4/1.5, moist) silty clay; weak, medium subangular blocky structure; horizon varies from 4 to 14 inches in thickness and may be absent as shown within a 6-foot horizontal distance; friable moist; slightly hard dry; calcareous.
Acb	50–59	Grayish-brown (10YR 5/2, moist) silty clay; weak, coarse prismatic structure; friable moist; slightly hard dry; noncalcareous.
C1b	59–68	Dark grayish-brown (10YR 4/2, moist) silty clay; weak, coarse prismatic structure; noncalcareous.

TABLE 21.—*Some physical properties of a Spearville silty clay loam profile*

Depth increments (inches)	Horizon	Particle size distribution [1]			Texture	Moisture retained at [2]—	
		Sand	Silt	Clay		⅓ atm.	15 atm.
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*
0–4½	Ap	11.6	49.0	39.4	Silty clay loam	33.78	14.92
4½–7½	B21	11.6	48.3	40.1	______do______	35.26	17.27
7½–17½	B22	11.6	40.4	48.0	Silty clay	37.56	21.57
17½–26	B23ca	5.8	46.2	48.0	______do______	37.14	20.99
26–33½	B3ca	8.6	47.4	44.0	______do______	36.65	20.06
33½–40	C1	10.8	46.8	42.4	______do______	37.23	18.90

[1] Particle size distribution by Bouyoucos method.
[2] Moisture retention by pressure membrane and pressure plate methods.

TABLE 22.—*Some chemical properties of a Spearville silty clay loam profile*

Depth increments (inches)	Horizon	$NaHCO_3$ extractable P	Total P	Total N	pH	Organic matter	Exchange-able K
		P.p.m.	*P.p.m.*	*Pct.*		*Pct.*	*P.p.m.*
0–4½	A1p	19.9	495	0.115	6.1	2.51	680
4½–7½	B21	15.5	495	.114	6.0	2.34	600
7½–17½	B22	2.4	458	.083	7.2	1.57	454
17½–26	B23ca	1.3	476	.072	7.4	1.08	441
26–33½	B3ca	.7	544	.048	7.7	.82	444
33½–40	C1	1.5	600	.039	7.7	.64	480

☆ U.S. Government Printing Office: 1967—O 266-303