THE RELATIONSHIP BETWEEN SOIL ANALYSIS AND CULTURAL PRACTICES OF A PEACH ORCHARD

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THE RELATIONSHIP BETWEEN SOIL ANALYSIS AND CULTURAL PRACTICES OF A PEACH ORCHARD

By

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A THESIS

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Information on the soil-mulch interrelationship will aid in the successful use of the sod-mulch system of soil management in Michigan peach orchards. The purpose of this experiment was to determine the nutritional status of the soil as influenced by mulching and fertilizer applications in the peach orchard.

Experimental Procedure

A peach orchard near Grand Rapids, Michigan contained mulched and unmulched blocks in which there were rows receiving nitrogen (N), nitrogen and phosphorus (NP), and nitrogen, phosphorus, and potassium (NPK). Trees which did not receive any fertilizer were used as a check. A Halehaven tree in each row was selected for soil sampling. Soil samples were taken in August 1952, at five soil depths: 0-4, 4-12, 12-20, 20-28, and 28-36 inches beneath each tree at three locations midway from the trunk to the outer branches. The soil samples were air-dried, crushed with a wooden pin, screened through a 2 mm. sieve, thoroughly mixed and stored in containers for analysis.

Soil pH was determined on a 1:1 soil water suspension with a Beckman model H-2 pH meter. Exchangeable calcium, magnesium, and potassium were determined by leaching a 20-gram soil sample with 200 milliliters of neutral normal ammonium acetate and measured with a Beckman model DU and model B spectrophotometers. The after leached original soil sample was then saturated with 40 milliliters of 10 per cent acidified sodium chloride solution and again leached with 100 milliliters of neutral normal ammonium acetate.

The leachate was collected for determining exchangeable sodium photometrically as a measure of the cation exchange capacity. Acetate soluble phosphorus was determined colorimetrically using the standard A. O. A. C. micro-method.

Results and Conclusions

The exchangeable calcium under mulch with fertilizer was lower than unmulched at all corresponding depths. The per cent calcium saturation under mulch and receiving fertilizer was steadily increased as the soil depths increased. Exchangeable magnesium was definitely lower under mulch with nitrogen fertilizer alone. When no fertilizer was applied, the mulched samples showed higher exchangeable magnesium than samples with no mulch. The per cent magnesium saturation under mulch with fertilizer was also lower than samples without mulch.

The exchangeable potassium was higher under mulch at 0-12 inch depths than in other soil depths when nitrogen, nitrogen and phosphorus, or nitrogen, phosphorus, and potassium fertilizer was applied, respectively. However, the amount at 0-12 inches under mulch without fertilizer was lower than the unmulched samples.

A higher cation exchange capacity was found at all soil depths under mulch than the unmulched samples when no fertilizer was applied. A higher exchange capacity and per cent base saturation was also found at the upper depths under mulch with fertilizer.

An increase of acetate soluble phosphorus occurred at the 0-4 inch depth under mulch with fertilizer. However, a great total amount of acetate soluble phosphorus was found from unmulched than from the mulched samples when no fertilizer was added.

The pH value at the surface soil was decreased under mulch when fertilizer was applied. There was a significant correlation of pH with per cent magnesium saturation, and a highly significant correlation of pH with per cent calcium saturation and with the total per cent saturation with calcium, magnesium, and potassium. A negative correlation of pH to acetate soluble phosphorus was also found highly significant.

The results of this investigation indicated that mulching influenced the nutritional status in the soil. In order to obtain the full advantage of complete fertilizers in such peach orchards, an adequate mulching program should be maintained and the use of dolomitic lime seems desirable.

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INTRODUCTION

Mulching is a cultural practice which has long been known to fruit growers. The influence of mulch on various soil properties as a direct result of adding inorganic and organic components to the soil, when decomposed, or as a sequence of rendering the soil constituents more available to plants is largely dependent upon the nature of the mulched material, the conditions and the inherent characteristics of the soil. Recently the sod-mulch system has been introduced in the Michigan peach orchards. In order to assure the success of such a cultural practice, the need of study on the soil-mulch inter-relationship is apparent.

An adequate supply of available nutrient-elements in soils is a fundamental requirement leading to the success of an orchard. A soil with high exchange capacity would be able to hold a greater quantity of essential nutrient-elements for use by the plant. Chemical analysis is usually employed as a tool for appraising soil fertility. With this thought in mind, the purpose of this experiment was to determine the nutritional status of the soil as influenced by mulching in a peach orchard.

REVIEW OF LITERATURE

Because of the possibility that nitrates may be reduced, some investigators have postulated that fruit trees received no benefits from the use of mulch on orchard soils. Albrecht (1922) studied nitrate accumulation under straw mulch and concluded that mulching with straw reduces the concentration of nitrates in the soil, and the only crops that did well were those that were able to obtain their nitrogen from this low concentration. Havis (1938) reported on a soil management study that the principal factor limiting the growth of the young peach trees in the blue grass sod and straw mulch has evidently been lack of nitrates. From a comparison of a permanent straw mulch with clean cultivation in a raspberry planting on a Sassafras sandy loam, Darrow and Magness (1938) stated that growth and fruiting under mulch were satisfactory but not superior to what was usually obtained with cultivation in good raspberry areas. However, the opposite effect of mulching on tree growth and nutrient relations in the soil has been noted by Beaumont, Sissions and Kelly (1927), Beaumont and Crooks (1933), Shaw and Southwick (1936), Clark (1940), Chandler and Mason (1949), and Shaw (1943). They verified that the increase of production and

vigor of tree growth was directly influenced by either the accumulation of nitrates or increased conservation of soil moisture as a result of mulching.

Soil constituents are the main source of mineral elements to plants. The quantity of these exchangeable mineral elements in soils is ordinarily altered to a certain degree by the addition of fertilizers alone or associated with the application of mulching. Merkle (1928) reported that a fertilizer experiment in Hagerstown silt loam soil showed that the amount of exchangeable calcium in the manured plot was about the same as that found on the unfertilized plot. However, those plots receiving either ammonium sulfate or dried blood with phosphorus and potash showed a reduction in exchangeable calcium, and the plots treated with nitrate of soda showed nearly five times as much exchangeable calcium as compared to the one receiving ammonium sulfate. Van Alstine (1918) stated that ammonium salts caused a marked loss of calcium as carbonate and this loss was proportionally related to an increase in acidity. A few years later, Wilson (1930) continued this study on three types of silt loam soils and concluded that the exchangeable calcium of the untreated soils was related to their hydrogen-ion concentration. When fertilizers were added to the soils in forms of nitrate of soda, acid phosphate and muriate of potash, with or without limestone, there was little or no effect on the quantity of exchangeable calcium found in the soils.

Mulching has been recognized by Shaw (1943), Harley, Moon and Regeimbal (1951) and Kenworthy and Gilligan (1948) as effectively liberating nutrient-elements directly to the soil. The nutrient-elements thus released were available to plants. In studies of the effect of mulch upon the exchangeable calcium in soils, Wander and Gourley (1943) using wheat straw on a Wooster silt loam in Ohio, and Weeks, Smith and Mack (1950), using low grade hay on Weathersfield loam in Massachusetts, concluded that the mulch increased the amount of exchangeable calcium as compared with cultivation in apple orchards. However, Wander and Gourley (1943) emphasized that the increase in exchangeable calcium was greater in the surface beneath the mulch and less in medium depths of 6-12 and 12-18 inches. Recently, Goodman (1953) put bluegrass hay, oat and wheat straw in separate rows as mulches and maintained a heavy permanent bluegrass sod as a control. He suggested that the "forced" migration of exchange calcium from the immediate soil surface under the hay mulch was due to the action of one or more acids formed during its decomposition.

A great number of investigators visualized that the adsorbed bases in the soil are replaced by other cations from their neutral salts in accordance with the lyotropic series. Wiegner and Jenny (1927) stated that the order of difficulty in displacement of the divalent cations from the soil complex was magnesium $<$ calcium $<$ barium, respectively. Mattson (1933) and Prince and Toth (1937) found that the percentage of exchangeable magnesium released was relatively low in comparison with the other exchangeable cations. Regardless of the pH or of other fertilizer salts present, according to Jamison (1946) magnesium is much more strongly retained than potassium in sandy soils.

It has been shown by Merkle (1928) that the heaviest applications of complete fertilizers resulted in the soil's becoming most nearly depleted in exchangeable magnesium in Hagerstown silt loam soil. Recently, Wander (1950) found that the addition of calcium phosphate increased the retention of exchangeable magnesium in sandy soil.

The influence of wheat straw mulch on the magnesium content of orchard soils has been studied by Wander and Gourley (1943). They stated that the exchangeable magnesium presents an unusual picture; highest values being found for the two lowest depths (12-18 and 18-24 inches) under cultivation, but in larger quantities at the two upper depths under mulch. According to Weeks, Tyson and Drake (1950), however, the exchangeable magnesium was increased at the lower soil depths (6-12 and 12-18 inches) under the low grade hay mulch in a bearing apple orchard.

Albrecht (1943) stated that within the colloidal crystal of clay, calcium is present in less than one-fifth the amount of the potassium. In their exchangeable forms, however, the calcium may be ten times as high as the potassium. These relations vary within different soils under different degrees of development. Dunkle, Merkle and Anthony (1939) summarized the results of their investigations of 47 commercial orchards and stated that more total potassium was found in the lower layers because of the greater clay content of the subsoils, especially all of the podzolic soils. Robinson (1914) obtained similar results. However, increased organic matter in the surface soil may result in a higher level of exchangeable potassium in the surface.

Van Alstine (1918) and Joffe and Kolodny (1936) stated that potassium, though easily and quickly fixed in soil, is more subject to movement within the soil as a result of applications of other salts. It was believed by Volk (1934) that potassium reacts with silicates to form difficultly soluble muscovite when the soil is allowed to become dry. In a study of lateral movement of potassium in an orchard soil, Wander and Gourley (1939) prepared 16 holes to a depth of 18 inches and introduced 85 grams of commercial potassium sulfate and 105 grams of superphosphate mixed with coarse sand into the lower 12 inches of the holes. The soil around the core was analyzed and an increase of about 100 to 200 p.p.m. of exchangeable potassium five to six inches away from the core was noted.

The increase of exchangeable potassium by the application of potash fertilizers has been reported by Merkle (1928), Wilson (1930), and Murphy (1934). Hoover (1944) pointed out that potassium may accumulate in the A horizon in replaceable form when applied in excess of plant needs, and DeTurk, Wood and Bray (1943) and Hoover (1944) stated that this accumulation increases as the rate of application increases. The surface soil, thus, often has a much higher amount of replaceable potassium than the B horizon. McGeorge (1933) showed that the exchangeable potassium was readily replaced from calcareous soils by ammonium salts, but not by calcium salts. However, Jenny and Shade (1934) liberated adsorbed potassium from soil colloids by the use of $CaCO_3$.

Mulching has the effect of increasing exchangeable potassium in the soil (Bregger and Musser 1939) and (Harley, Moon and Regeimbal 1951). In a study of the mobilization of the exchangeable potassium in the soil, Reuther (1941) applied straw as the mulch material to a Dunkirk silt loam soil for four years in New York and found that the exchangeable potassium was markedly increased in the first 24 inches of the soil as compared to sod and cultivation treatments.

Wander and Gourley (1937, 1938) reported an increase of the exchangeable potassium even to the depth of from 24 to 32 inches and sometimes as deep as 40 inches in the Wooster silt loam soil as the result of using old wheat straw mulch for 38 years. Boller and Stephenson (1946) collected soil samples from a raspberry field which had been mulched for ten years in Oregon and showed that the soluble potassium was increased in the first six inches. According to Weeks, Tyson and Drake (1950), the amount of exchangeable potassium under a mulch was increased at the 6- and 18-inch soil depths as compared to the cultivated plots.

When potash fertilizer was added to a straw or soybean mulch, Wander and Gourley (1945) showed that the available potassium content was immediately increased. In addition to the increase in available potassium in the 0-4 inch depth of the soil, the 4-8 inch depth showed a definite increase; while there was no effect at the 12-18 inch depth after a 3-year period. Apparently, the increase of available potassium is dependent, in part, upon the type of mulch material. Nearpass, Drosdoff and Brown (1948) found no increase in soil potassium when a vetch mulch was used, but a crotalaria mulch resulted in a higher soil potassium level in the 6-18 inch depth.

It has long been known that the reverting or fixing power of the soil for phosphates is ordinarily in proportion to the content of iron, aluminum and calcium in the soil. Swenson, Cole and Sieling (1949) reported that within the range of 2.5 to 4.0 pH the precipitates of iron and aluminum phosphate were dihydroxy dihydrogen phosphates. In an x-ray study, Haseman, Brown and Whitt (1950) stated that complex iron and aluminum phosphates were similar to the palmerite pattern, which was identified in some of the phosphates related to illite. Cole and Jackson (1950) studied the crystalline character of some iron and aluminum phosphates and showed that these precipitates consisted mainly of such crystal species as sterrettite, variscite and strengite.

Jensen (1928) and Wander and Gourley (1939) pointed out that phosphorus, when applied as phosphate fertilizer, moves laterally in the soil only slightly. Since the iron, aluminum and calcium elements occur largely in the finer separates of soil such as silt, clay and colloidal material, the sand and sandy type of soils thus would naturally have lower phosphate fixing power (Bryan 1933). Alway and Rost (1916) found a steady decrease in phosphorus from the surface inch downward in the first foot of the prairie loess soils. A similar result was obtained by Harding (1953) in California orange orchard soils.

According to Midgley (1931), there was a very marked difference in the movement of phosphatic salts through soils. In the case of sodium phosphate, ammonium phosphate and potassium phosphate, 88, 3.3 and 3.2 per cent, respectively, of the phosphates were leached out. Spencer and Stewart (1934) also found that phosphorus in the form of di-sodium phosphate penetrates the soil more readily than that applied as superphosphate. Such difference might account for the fact that Smith (1949) found no benefit from the superphosphate in the orange groves.

Wander (1947) applied two pounds of 20% superphosphate per tree, with wheat straw as a mulch, in a Stayman Winesap apple orchard for a period of three years and found that the depth of penetration of available phosphorus into the soil was slightly increased. A more pronounced effect of mulch upon the vertical movement of available phosphorus into the soil was obtained by Weeks, Tyson and Drake (1950). They concluded from their experiment in a bearing apple orchard that the amount of available soil phosphorus in the plots mulched with low grade hay was six times more at the 0-6-inch level and five times more at the 6-12 and 12-18-inch level than the corresponding levels of the cultivated plots. Organic matter could have facilitated the more rapid penetration of phosphorus through the soil (Stephenson and Chapman 1931). The use of rye grass or fescue straw as mulch was found to have no effect on phosphorus mobility by Boller and Stephenson (1945).

Exchange capacity is an indication of the soil's capacity to retain essential elements in a form readily available to plants, and is related to the amount of clay and organic matter in the soil. Albrecht (1941) stated that ion adsorption and ion exchange are physical and chemical processes taking place in organic matter, and that the humus fraction has from 2 to 6 times more exchange capacity per unit weight than the clay fraction. Reuther (1941) found mulch treatment appeared to have increased the exchange capacity of the soil slightly when compared to sod or cultivation treatments in a McIntosh apple orchard.

The total replaceable hydrogen in the soils with a high colloid fraction increases with the degree of unsaturation. Joffe and McLean (1927) indicated that the degree of saturation or unsaturation of the top and subsurface soil gives a picture of the process of podsolization and the fate of the cations replaced. The subsoils, therefore, showed a higher degree of saturation than the surface soils of similar pH values. In general, it was found that the highly weathered soils have a lower degree of saturation at a given pH value than less weathered soils. Furthermore, there was no relationship between the organic matter content of soils and the per cent base saturation of the soils at similar pH values (Pierre and Scarseth 1931). The base saturation of a light sandy soil is increased from 25 to 75% by increasing the pH of a soil from 5 to 6 (Peech 1941).

EXPERIMENTAL PROCEDURE

An orchard of one-year-old peach trees was planted in Miami silt loam on April, 1948 at the Graham Horticulture Experiment Station, Grand Rapids, Michigan. The orchard contained Redhaven, Halehaven and Elberta varieties. Each row contained three trees of each variety with additional border trees of Redhaven and Halehaven. The orchard was divided into three portions. A Chewing fescue sod was established on the area, including rows 1 to 6 and 10 to 15. Rows 7 to 9 were clean cultivated with a rye cover crop. The trees in rows 10 to 15 were mulched. The initial mulching was with 30 to 40 pounds of straw per tree in 1948. Fifty pounds of weedy hay was added in July of 1950 to each of the mulched trees. The mulch was applied over an area extending from the trunk to the perifery of the tree.

The trees in rows 1 and 15 did not receive any fertilizer and were used as a check. All of the remaining trees were given commercial fertilizers of various analyses in varying amount, depending on the age of the trees. The trees growing in sod or sod-mulch and receiving the higher rates of application of nitrogen (4 and 12), nitrogen and phosphorus (2 and 10), and nitrogen, phosphorus and potassium (3 and 11) were selected for soil sampling.

Nitrogen (20-0-0) was applied to individual trees at rates of 0.67 pounds in 1949, 1.33 pounds in 1950, 2.0 pounds in 1951 and 2.67 pounds in 1952. Phosphorus (0-20-0) was applied at rates of 6.0 pounds in 1948, 2.0 pounds in 1950, 2 pounds in 1951, and 4.0 pounds in 1952. Potassium (0-0-20) was applied at rates of 6.0 pounds in 1948, 2.0 pounds in 1950 and 4.0 pounds in 1952.

Collection of Soil Samples

A Halehaven tree in each of the rows was selected for soil sampling. The soil samples were taken in August, 1952, with a Veihmeyer soil tube. The samples were taken at five soil depths: 0-4, 4-12, 12-20, 20-28 and 28-36 inches. Three samples were taken beneath each tree at a position midway from the trunk to the outer branches. One sample was taken from each of the row middles. Each sample from each depth was stored in a round pint food container (Sealright). After the samples were air-dried, they were crushed with a wooden pin, screened through a 2 mm. sieve, thoroughly mixed and stored in the original container for analysis.

Soil Analysis

The samples were analyzed in duplicates for pH, exchangeable calcium, exchangeable magnesium, exchangeable potassium, acetate soluble phosphorus and exchange capacity. Soil pH was determined on a 1:1 soil-water suspension by use of a Beckman model H-2 pH meter with a glass electrode.

For the determination of exchangeable calcium, magnesium and potassium a soil extract was prepared by agitating a 20 gram sample with 100 ml. of neutral normal ammonium acetate for 30 minutes. After agitation, the sample was filtered and washed with an additional 100 ml. of ammonium acetate and brought to 200 ml. volume.

A 10 ml. aliquot was used for the determination of exchangeable calcium and magnesium. The remaining leachate was evaporated to dryness with infrared lamps, ignited at 400° C in a furnace for 5-6 hours. The ash was then dissolved with a few drops of concentrated hydrochloric acid and dried with infrared lamps. When dry, the residue was dissolved with 25 ml. of 1.0 per cent hydrochloric acid and filtered. The filtrate was used to determine exchangeable potassium and acetate soluble phosphorus.

Exchange capacity was determined by using the original 20 gram soil sample. After extracting with neutral normal ammonium acetate, the sample was washed with 50 ml. of 95 per cent ethyl alcohol. The exchange complex was saturated with sodium by washing with 40 ml. of 10 per cent sodium chloride. To remove the excess sodium chloride, the sample was then washed with 100 ml. of 95 per cent ethyl alcohol. The soil was then leached with 100 ml. of neutral normal ammonium acetate and the leachate used to determine exchangeable sodium as a measure of the cation exchange capacity.

Acetate soluble phosphorus was determined colorimetrically, using the standardized A. O. A. C. method. A Beckman model B spectrophotometer with a flame attachment was used for determining calcium, potassium and sodium, using an acetylene-oxygen flame. A Beckman model DU spectrophotometer with a flame attachment was used for determining magnesium, using a hydrogen-oxygen flame. Calcium was measured by using a wave length of 554 millimicrons and a slit width of 0.28 mm.; magnesium, a wave length of 371 millimicrons with a slit width of 0.538 mm.; potassium, wave length of 762 millimicrons with a slit width of 0.1 mm.; sodium, wave length of 585 millimicrons with a slit width of 0.05 mm.

Exchangeable calcium, magnesium, potassium and cation exchange capacity were expressed as m.e. per 100 gm. of dry soil. Exchangeable calcium, magnesium and potassium were also calculated as per cent saturation of the cation exchange capacity.

RESULTS

Exchangeable Calcium

In an exchangeable form, calcium is the most abundant base in mineral soils. The amount of this element, in general, increased with soil depth. The content of exchangeable calcium found at each soil depth from the various treatments is given in Table 1. The data showed that the lowest amount of this element (1.48 m.e./100 gram) occurred at the first soil depth (0-4 inches) in ammonium nitrate fertilized plots that had been mulched for a 4-year period. The highest amount (7.685 m.e./100 gram) of this element was found at the fifth soil depth (28-36 inches) of the unfertilized mulched plots.

In Figure 1, the graphs show that the upper soil layers (0-12 inches) had a lower content of exchangeable calcium regardless of mulching. All samples under mulch with addition of fertilizer had a lower amount of calcium in all soil depths as compared with the unmulched samples. However, reversed trend was found at the lower soil depths (12-36 inches) of the check samples where the content of exchangeable calcium was consistently higher for the mulched samples than for the unmulched samples at the corresponding depths.

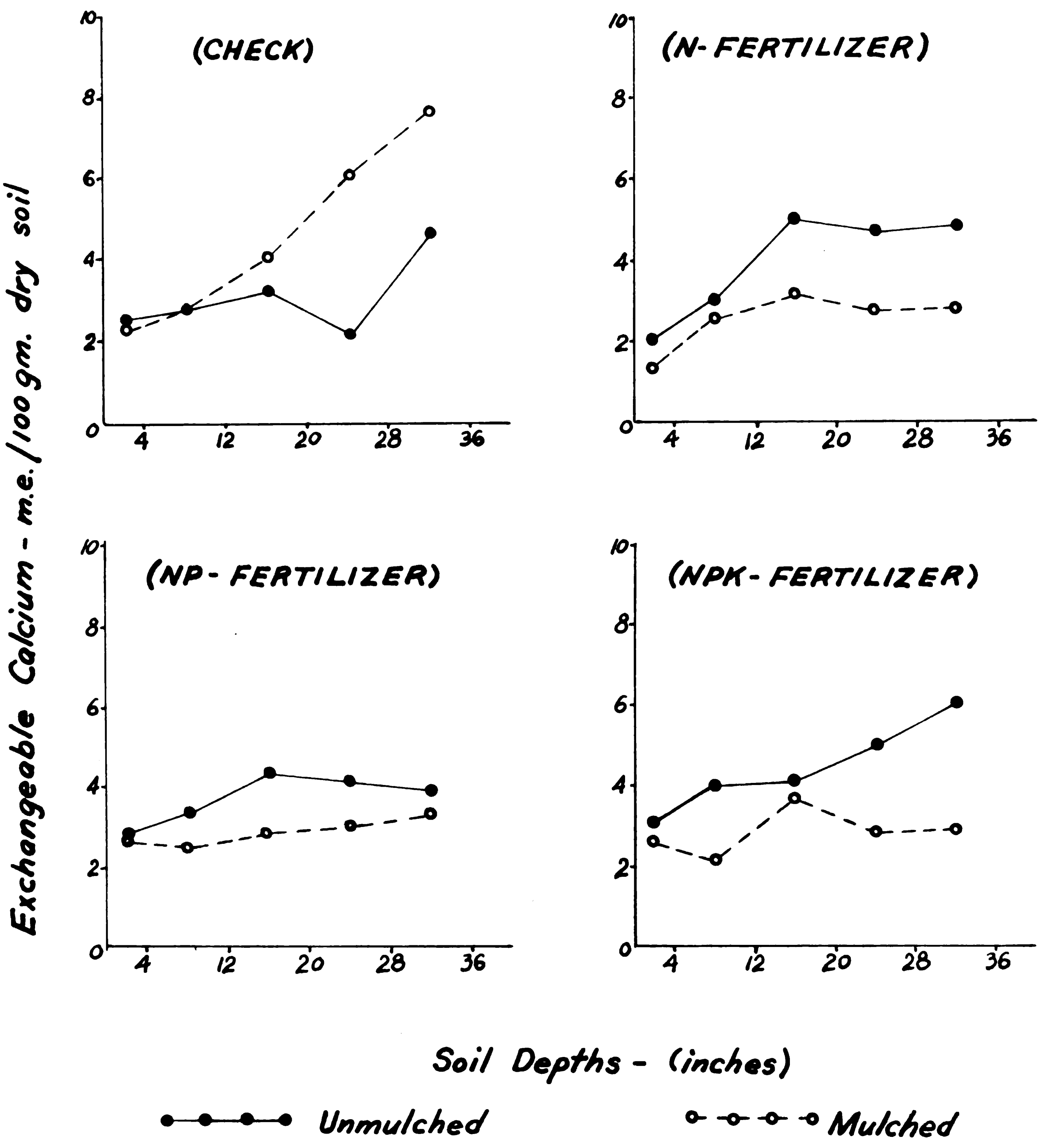
TABLE 1

EXCHANGEABLE CALCIUM AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES -- m.e./100 gm. Soil

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	2.595	2.878	3.293	2.245	4.740	3.150	
	N	2.129	3.027	5.106	4.807	4.890	3.992	
	NP	2.828	3.376	4.308	4.125	3.875	3.702	
	NPK	3.127	4.059	4.158	5.007	6.121	4.494	
	Average	2.670	3.335	4.216	4.046	4.907	3.835	
Mulched	Check	2.412	2.944	4.125	6.171	7.685	4.667	3.908
	N	1.480	2.578	3.243	2.678	2.861	2.568	3.280
	NP	2.744	2.495	2.944	3.077	3.410	2.934	3.318
	NPK	2.645	2.229	3.709	2.844	2.977	2.881	3.688
	Average	2.320	2.562	3.505	3.693	4.233	3.263	
	Average for depths	2.495	2.949	3.861	3.870	4.570		

Least significant difference:	0.05	0.01
Between depths	1.033	1.448
Cultural practices X fertilizer	1.405	1.830

Figure 1. Exchangeable calcium at different soil depths as influenced by fertilizer and cultural practices.


(CHECK)
(N-FERTILIZER)
(NP-FERTILIZER)
(NPK-FERTILIZER)
Exchangeable Calcium - m.e./100 gm. dry soil
0
2
4
6
8
10
4
12
20
28
36
Soil Depths - (inches)
Unmulched
Mulched

Analyses of variance indicated a significant interaction between cultural practices and fertilizer application and a highly significant difference between soil depths. When no fertilizer was applied, the mulched samples were higher than the unmulched samples. Whereas, when NPK-fertilizer was applied the mulched samples had lower amount of exchangeable calcium than the unmulched samples. In respect to depth, the 28-36 inch samples were higher than the 0-4 inch samples.

Per Cent Calcium Saturation of Exchange Capacity

The per cent saturation of the cation exchange capacity with calcium is presented in Table 2. The data show that the lowest per cent saturation (10.72) with calcium occurred at the first soil depth (0-4 inches) under mulch with nitrogen. The highest value of 69.25 per cent calcium saturation was found at the fourth soil depth (20-28 inches) for the check samples with no mulch.

The graphs in Figure 2 show that the per cent calcium saturation for samples under mulch and receiving fertilizer was steadily increased as the soil depth increased. The upper depths (0-12 inches) of the fertilizer-mulched samples had a lower calcium saturation than the fertilizer-unmulched samples. However, a higher per cent saturation with calcium occurred at the lower depths (20-36 inches) for the mulched than the unmulched samples with the same fertilizer treatment.

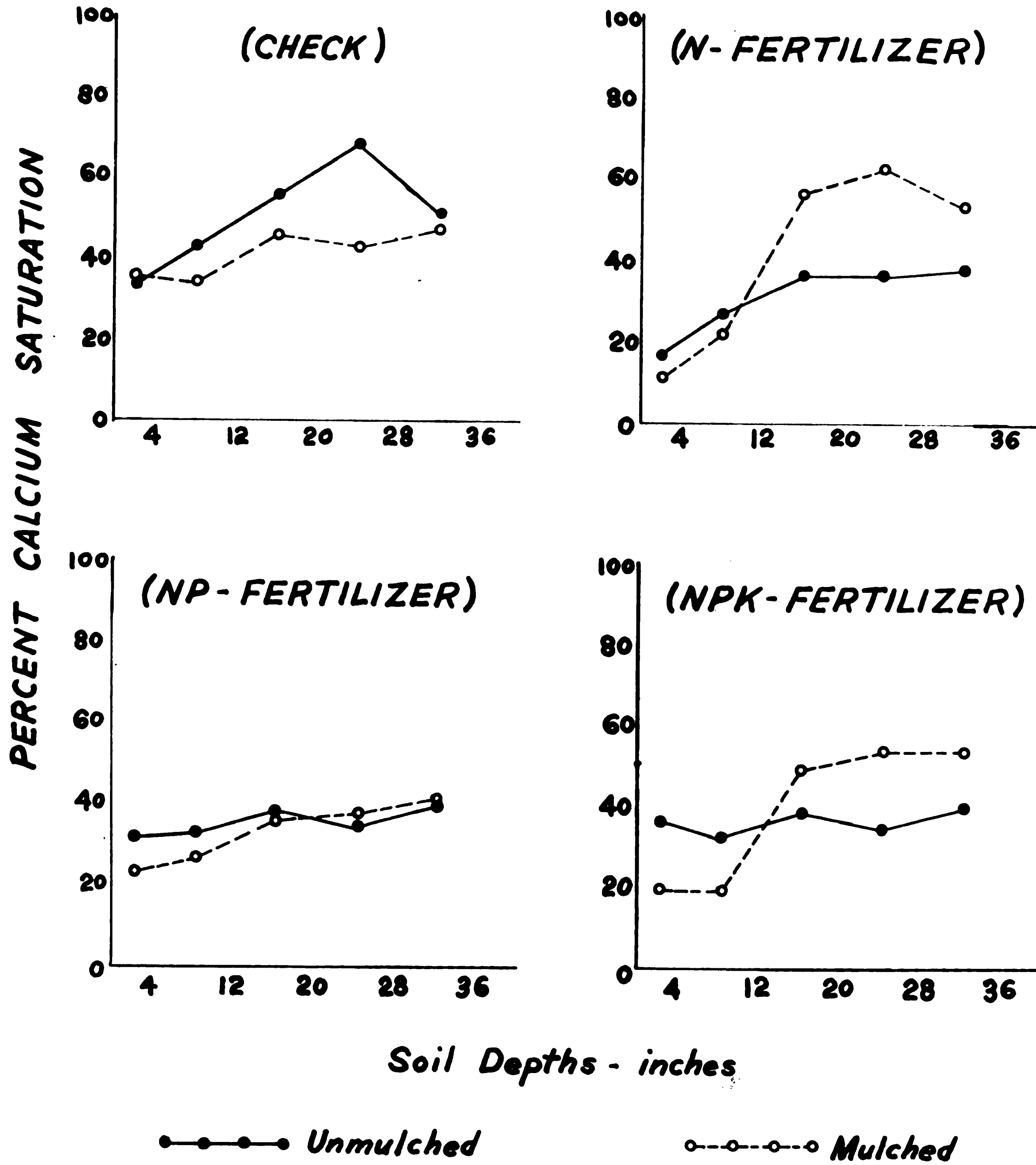
TABLE 2

PER CENT CALCIUM SATURATION AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	34.41	43.73	55.62	69.25	51.06	50.81	
	N	17.12	27.62	36.14	36.44	38.97	31.25	
	NP	31.53	32.88	38.35	34.70	39.88	35.46	
	NPK	25.37	32.48	38.34	32.30	38.80	33.46	
	Average	27.11	34.15	42.11	43.17	42.18	37.74	
Mulched	Check	35.37	34.49	45.89	43.61	46.90	41.25	46.03
	N	10.72	21.69	56.18	62.73	54.38	41.14	36.20
	NP	22.76	26.43	35.47	37.69	40.74	32.62	34.04
	NPK	19.93	19.30	48.82	53.33	53.36	38.95	36.21
	Average	22.20	25.48	46.59	49.34	48.85	38.49	
	Average for depths	24.66	29.82	44.35	46.26	45.52		

Least significant difference:	0.05	0.01
Between fertilizers	7.50	10.51
Between depths	8.41	11.79

Figure 2. Per cent calcium saturation at different soil depths as influenced by fertilizer application and cultural practices,


(CHECK)
(N- FERTILIZER)
(NP - FERTILIZER)
(NPK - FERTILIZER)
PERCENT CALCIUM SATURATION
0
20
40
60
80
100
4
12
20
28
36
Soil Depths - inches
Unmulched
Mulched

The mulched samples without fertilizer treatment showed a higher per cent calcium saturation at the first depth (0-4 inches) and lower percentage at the four lower depths (4-36 inches) as compared with the unmulched soil samples.

Analyses of variance showed a significant difference between fertilizers and a highly significant difference between soil depths. The per cent calcium saturation in the samples without fertilizer was higher than in the samples with NP-fertilizer. For soil depth, the lower depths 20-36 inches) had a higher per cent calcium saturation than the upper depths (0-12 inches).

Exchangeable Magnesium

The behavior of exchangeable magnesium in soil was very similar to that of exchangeable calcium, but shows more pronounced movement in relation to fertilizer application. The quantity of exchangeable magnesium at various soil depths as influenced by fertilizer application and cultural practices is given in Table 3. Soil from the first depth (0-4 inches) of the unmulched samples with addition of nitrogen and phosphate fertilizer contained the lowest amount (0.164 m.e./100 gram) of exchangeable magnesium. The highest content (4.112 m.e./100 gram) of this element occurred at the last sampling depth (28-36 inches). In general, exchangeable magnesium increased with soil depth.

TABLE 3

EXCHANGEABLE MAGNESIUM AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES --m.e./100 gm. Soil

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	0.795	0.850	0.932	0.439	1.864	0.976	
	N	0.630	1.097	2.275	2.604	3.646	2.050	
	NP	0.164	0.575	1.891	2.029	1.535	1.239	
	NPK	0.329	0.740	1.316	2.193	4.112	1.738	
	Average	0.480	0.816	1.604	1.816	2.789	1.501	
Mulched	Check	0.603	0.740	1.261	2.412	4.112	1.826	1.401
	N	0.357	0.302	0.466	0.329	0.438	0.378	1.214
	NP	0.219	0.247	0.685	0.740	0.822	0.543	0.891
	NPK	0.521	0.411	0.685	0.576	0.521	0.543	1.141
	Average	0.425	0.425	0.774	1.014	1.473	0.823	
	Average for depths	0.453	0.621	1.189	1.415	2.131		

Least Significant Difference:	0.05	0.01
Between cultural practices	0.589	0.825
Between depths	0.930	1.304
Cultural practices X fertilizer	1.176	1.638

Analyses of variance showed a significant difference between cultural practices and soil depths and a significant interaction of cultural practices with fertilizers. The unmulched samples had a higher quantity of exchangeable magnesium than the mulched samples. Samples from 28-36 inches were higher than 0-12-inch samples. When nitrogen was applied, the samples under mulch were lower in magnesium than the unmulched samples.

Figure 3 shows that the amount of exchangeable magnesium at the two upper depths (0-12 inches) of the check samples was lower for mulch than for the unmulched samples, but increased consistently toward the lower depths. Unmulched samples with addition of fertilizers showed a marked increase in this element from the top to the lower soil depths. Although there were some increases in exchangeable magnesium found for the deeper soil samples under mulching, it was definitely lower in quantity for the mulched samples where fertilizer had been added.

Per Cent Magnesium Saturation of Exchange Capacity

Per cent magnesium saturation of the cation exchange capacity at different soil depths as related to fertilizer application and cultural practices is shown in Table 4. The lowest saturation with magnesium was found at the first depth with a value of 1.83 per cent for the mulched samples

Figure 3. Exchangeable magnesium at different soil depths as influenced by fertilizer application and cultural practices

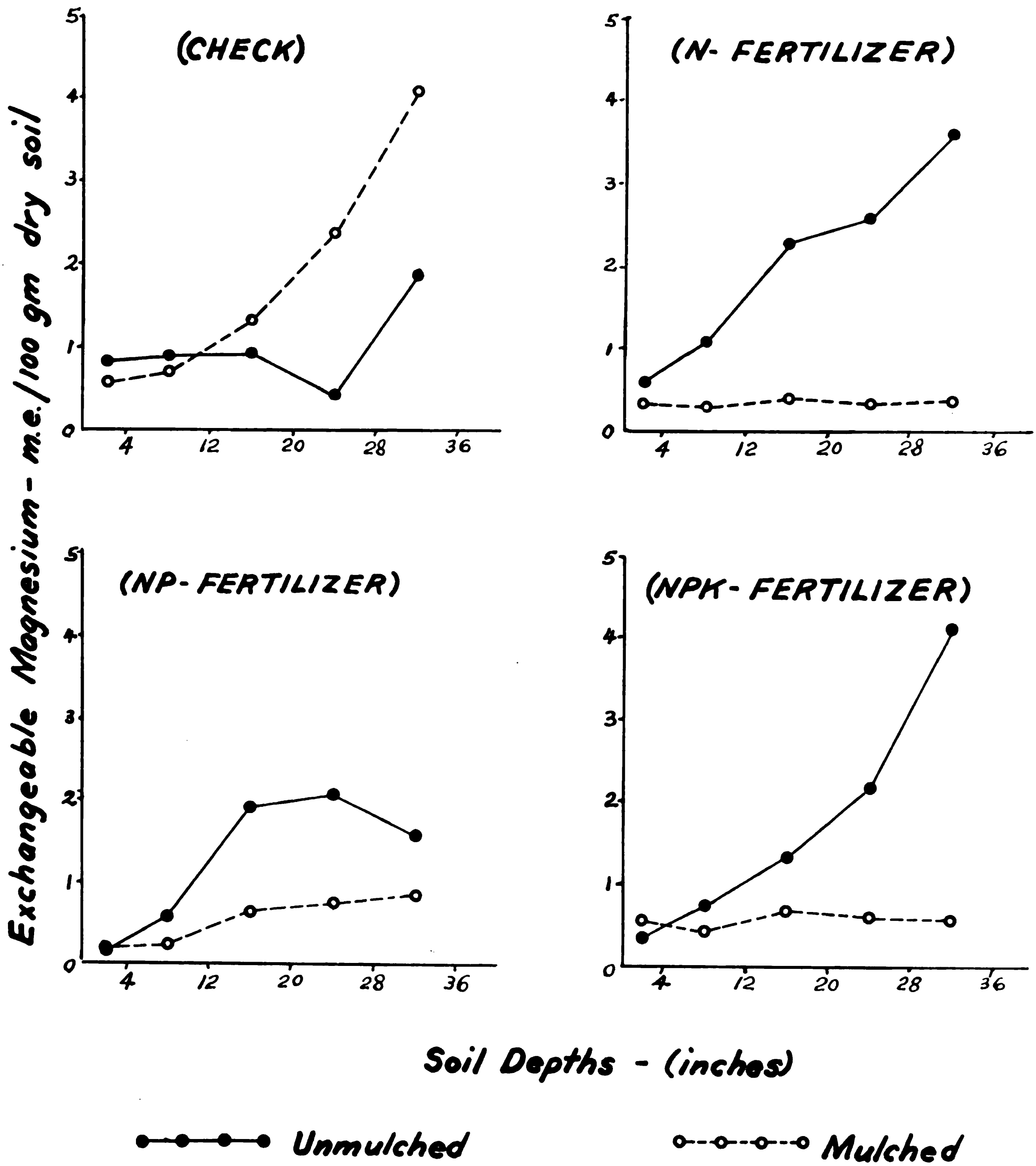

(CHECK)
(N- FERTILIZER)
(NP- FERTILIZER)
(NPK- FERTILIZER)
Exchangeable Magnesium - m.e./100 gm dry soil
0
1
2
3
4
5
4
12
20
28
36
Soil Depths - (inches)
Unmulched
Mulched

TABLE 4

PER CENT MAGNESIUM SATURATION AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	11.19	13.20	15.29	13.32	17.69	14.14	
	N	5.48	10.04	16.10	19.26	29.14	16.00	
	NP	2.11	5.01	16.86	16.32	16.43	11.35	
	NPK	2.63	5.85	11.58	13.96	26.14	12.03	
	Average	5.35	8.53	14.96	15.72	22.35	13.38	
Mulched	Check	6.03	7.98	10.77	14.70	23.43	12.58	13.36
	N	2.59	2.52	7.68	7.54	8.03	5.67	10.83
	NP	1.83	2.62	7.92	9.04	9.78	6.24	8.79
	NFK	3.90	3.53	8.65	10.40	9.04	7.10	9.56
	Average	3.59	4.16	8.76	10.42	12.57	7.90	
	Average for depths	4.47	6.35	11.86	13.07	17.46		

Least Significant Difference	0.05	0.01
Between cultural practices	2.79	3.900
Between depths	4.42	6.20

with NP-fertilizer samples. The highest value of 29.14 per cent occurred at the lowest soil depth (28-36 inches) under mulch with addition of nitrogen.

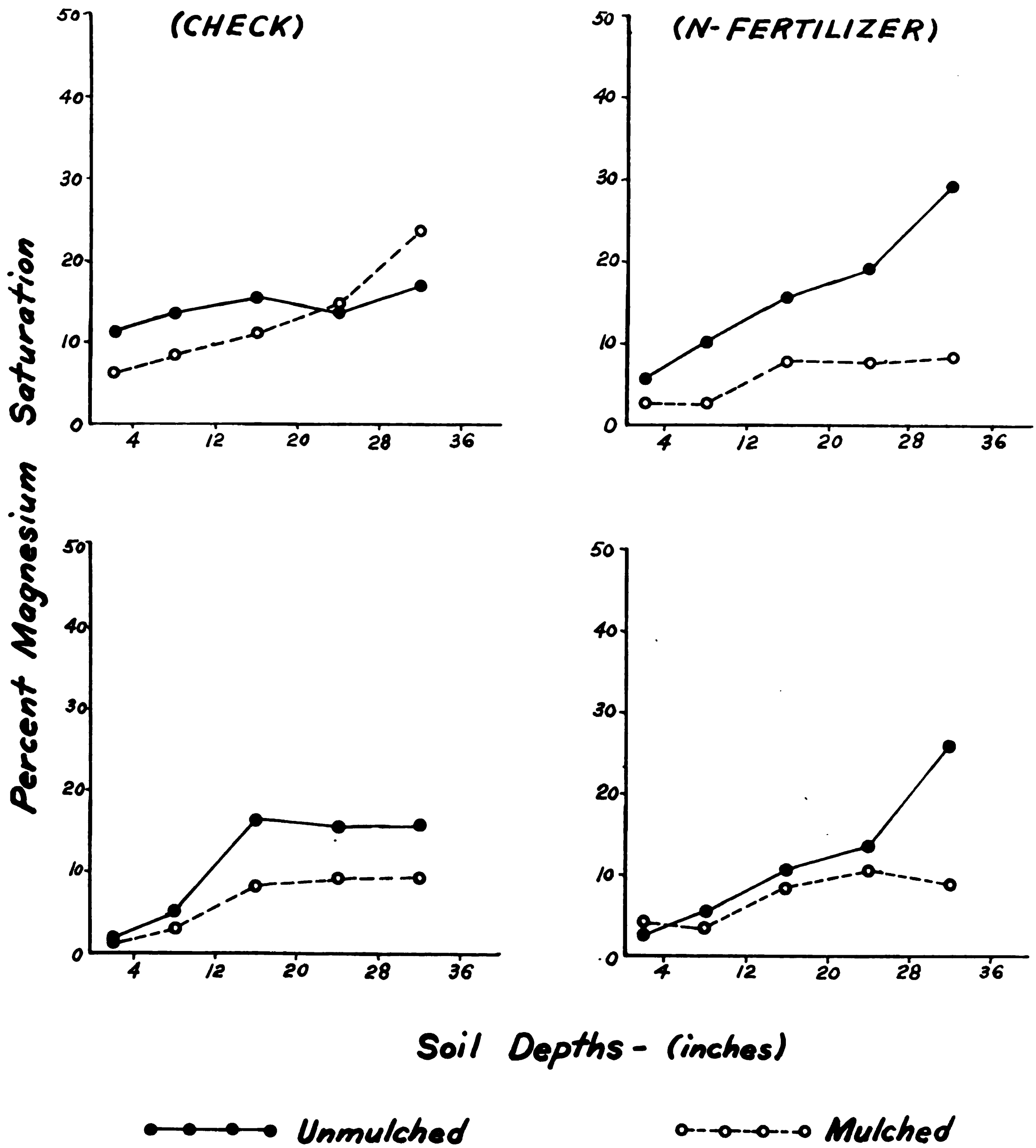
Figure 4 shows that, when mulched, the check samples had a much higher saturation with magnesium than those samples that received fertilizer applications with mulching.

Analyses of variance showed a highly significant difference between soil depths and between cultural practices. The unmulched samples had a much higher per cent magnesium saturation than the mulched samples. At soil depths, the lower depth (28-36 inches) samples had a higher per cent magnesium saturation than samples taken from 0-12 inches. Likewise, samples of 20-36 inches were higher than samples from 0-4 inches.

Exchangeable Potassium

The quantity of exchangeable potassium in the soil extract was rather small as compared with calcium and magnesium. The relation of exchangeable potassium at different soil depths to the fertilizer and cultural practices is presented in Table 5. The lowest concentration of this element was found in samples at the first soil depth under no mulch with the addition of NP-fertilizer. The highest concentration, however, was found at the first soil depth of the mulched samples which had received NPK-fertilizer.

Figure 4. Per cent magnesium saturation at different soil depths as influenced by fertilizer application and cultural practices



(CHECK)
(N-FERTILIZER)
Percent Magnesium Saturation
0
10
20
30
40
50
4
12
20
28
36
Soil Depths - (inches)
Unmulched
Mulched

TABLE 5

EXCHANGEABLE POTASSIUM AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES -- m. e./100 gm. Soil

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	0.116	0.085	0.056	0.027	0.096	0.076	
	N	0.067	0.066	0.085	0.132	0.092	0.088	
	NP	0.018	0.035	0.071	0.070	0.045	0.048	
	NPK	0.273	0.156	0.042	0.038	0.035	0.109	
	Average	0.118	0.086	0.064	0.067	0.067	0.080	
Mulched	Check	0.104	0.076	0.074	0.092	0.131	0.095	0.086
	N	0.087	0.092	0.038	0.032	0.033	0.056	0.072
	NP	0.106	0.080	0.065	0.058	0.061	0.074	0.061
	NPK	0.479	0.335	0.123	0.053	0.051	0.208	0.159
	Average	0.194	0.146	0.075	0.059	0.069	0.108	
	Average for depths	0.156	0.116	0.070	0.063	0.068		

Least significant difference:	0.05	0.01
Between cultural practices	0.026	0.0367
Between fertilizers	0.037	0.0519
Between depths	0.0407	0.0671
Cultural practices X fertilizer	0.0514	0.0721

The common trend of exchangeable potassium at different soil depths under the influence of various fertilizer and cultural practices is shown in Figure 5. Samples under mulch with phosphorus showed a decrease in quantity of potassium as the soil depth increased. The check samples under both mulch and without mulch showed a decrease from the top down to the middle depths and an increase at the lower depths. However, both mulched and unmulched samples had a considerably lower amount of potassium at the first soil depth (0-4 inches) when nitrogen was applied. Samples from the NPK-fertilizer treatment had much higher quantity of exchangeable potassium at all soil depths for the mulched than for the unmulched samples. Apparently, mulching resulted in less fixation of potassium and promoted its migration into the soil.

Analyses of variance indicated that differences between cultural practices and the interaction of cultural practices with fertilizer was significant. The differences between fertilizers and soil depths and the interaction of soil depths with fertilizers were highly significant. These significant differences were, in general, associated with the influence of mulching upon the fixation and movement of potassium applied with the NPK-fertilizer.

Per Cent Potassium Saturation of Exchange Capacity

In Table 6 the per cent potassium saturation of the exchange capacity at different soil depths is presented in

Figure 5. Exchangeable potassium at different soil depths as influenced by fertilizer application and cultural practices

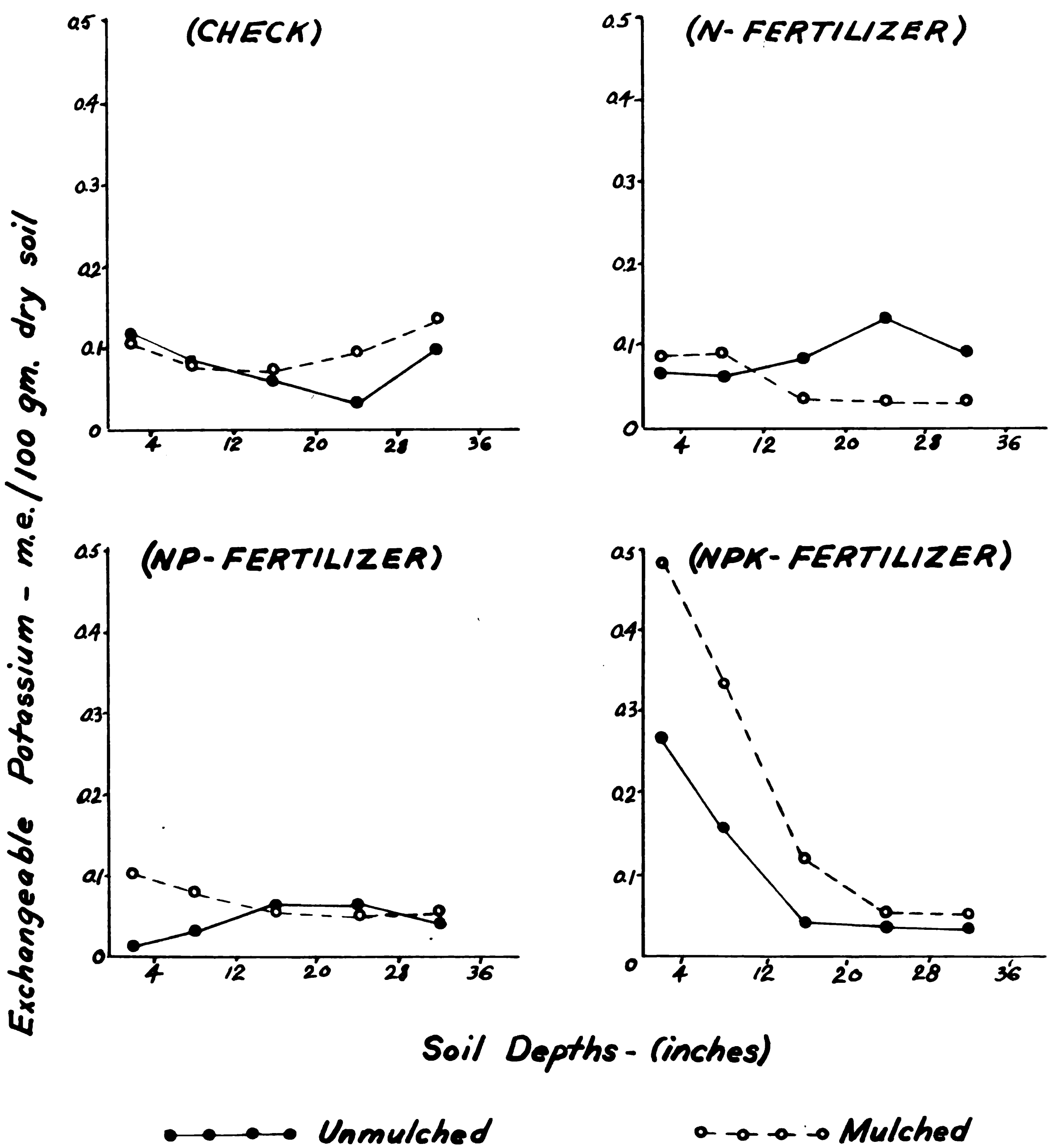

(CHECK)
(N- FERTILIZER)
(NP- FERTILIZER)
(NPK- FERTILIZER)
0.5
0.4
0.3
0.2
0.1
0
4
12
20
28
36
Exchangeable Potassium - m.e./100 gm. dry soil
Soil Depths - (inches)
Unmulched
Mulched

TABLE 6

PER CENT POTASSIUM SATURATION AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES

Cultural practice	Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	1.68	1.25	0.99	0.84	1.01	1.15	
	N	0.54	0.63	0.59	1.05	0.72	0.71	
	NP	0.18	0.32	0.63	0.58	0.48	0.44	
	NPK	2.18	1.26	0.42	0.26	0.22	0.87	
	Average	1.15	0.87	0.66	0.68	0.61	0.79	
Mulched	Check	1.03	0.82	0.75	0.66	0.85	0.82	0.99
	N	0.63	0.76	0.68	0.75	0.65	0.69	0.70
	NP	0.88	0.85	0.74	0.65	0.73	0.77	0.61
	NPK	3.63	2.76	1.67	1.01	0.90	1.99	1.43
	Average	1.54	1.30	0.96	0.77	0.78	1.07	
	Average for depths	1.35	1.09	0.81	0.73	0.70	0.93	

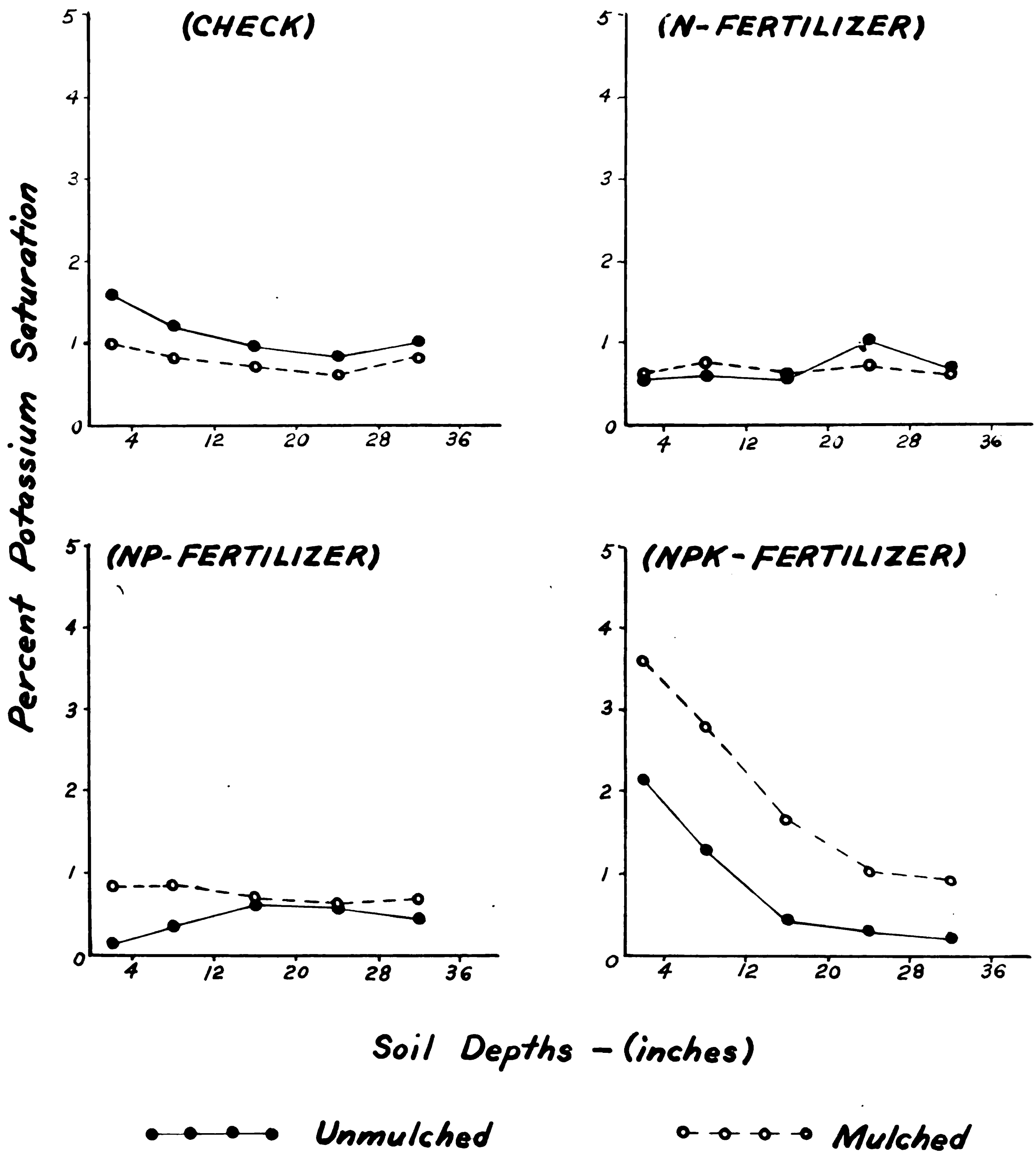
Least significant difference:	0.05	0.01
Between cultural practices	0.13	0.18
Between fertilizers	0.19	0.26
Between depths	0.21	0.29
Cultural practices X fertilizer	0.26	0.37

relation to the use of fertilizer and cultural practices. Only 0.18 per cent saturation was found at the first soil depth for the unmulched samples with the addition of NP-fertilizer. This was the lowest value among the soil samples. The highest value was 3.63 per cent which was found at the first depth of the samples under mulch with addition of NPK-fertilizer. The average value of 1.07 per cent saturation for the mulched samples indicated a higher saturation for mulching than for the unmulched samples with an average of 0.79 per cent.

In Figure 6 the graphs indicate that the check samples under unmulched had a higher per cent saturation of potassium than the samples under mulch at all depths. Samples that received nitrogen fertilizer had a higher per cent saturation at the upper three depths (20-36 inches) when mulched than when unmulched. There was a very pronounced increase in per cent potassium saturation at all depths under mulch when NPK-fertilizer was applied. The increase in per cent potassium saturation for NPK-fertilizer without a mulch was restricted to the 0-12 inch depths.

Analyses of variance showed a highly significant difference between cultural practices, fertilizers and soil depths. The interactions of cultural practices with fertilizer and fertilizers with soil depths were highly significant. The mulched samples had a higher per cent

Figure 6. Per cent potassium saturation at different soil depths as influenced by fertilizer application and cultural practices



(CHECK)
(N-FERTILIZER)
(NP-FERTILIZER)
(NPK-FERTILIZER)
Percent Potassium Saturation
0
1
2
3
4
5
4
12
20
28
36
Soil Depths – (inches)
Unmulched
Mulched

saturation than unmulched ones. Regarding fertilizer treatments, NPK-fertilizer was the highest. For soil depth, the first depth (0-4 inches) was higher than the other three lower depths (12-36 inches); the 4-12 inch samples were also higher than samples taken from 28-36 inches. Interactions of cultural practices with fertilizer applications and soil depth showed that the influence of mulching in preventing fixation and upon the downward movement of potassium was significant.

Cation Exchange Capacity

The exchange capacity at different soil depths under different cultural practices with the addition of fertilizer is given in Table 7. A wide range (from 3.24 to 16.26 m.e./100 grams) was found with an average of 10.248 m.e./100 grams for all samples. The two upper soil depths of mulched samples with fertilizers generally had a higher exchange capacity than the lower depths. However, the higher exchange capacity occurred at the lowest depths of the check samples under mulch.

The relationship of exchange capacity to fertilizer application and cultural practices is shown graphically in Figure 7. At the first depth the mulched samples had a higher exchange capacity than the unmulched samples. The effect of mulch upon the exchange capacity of soils was

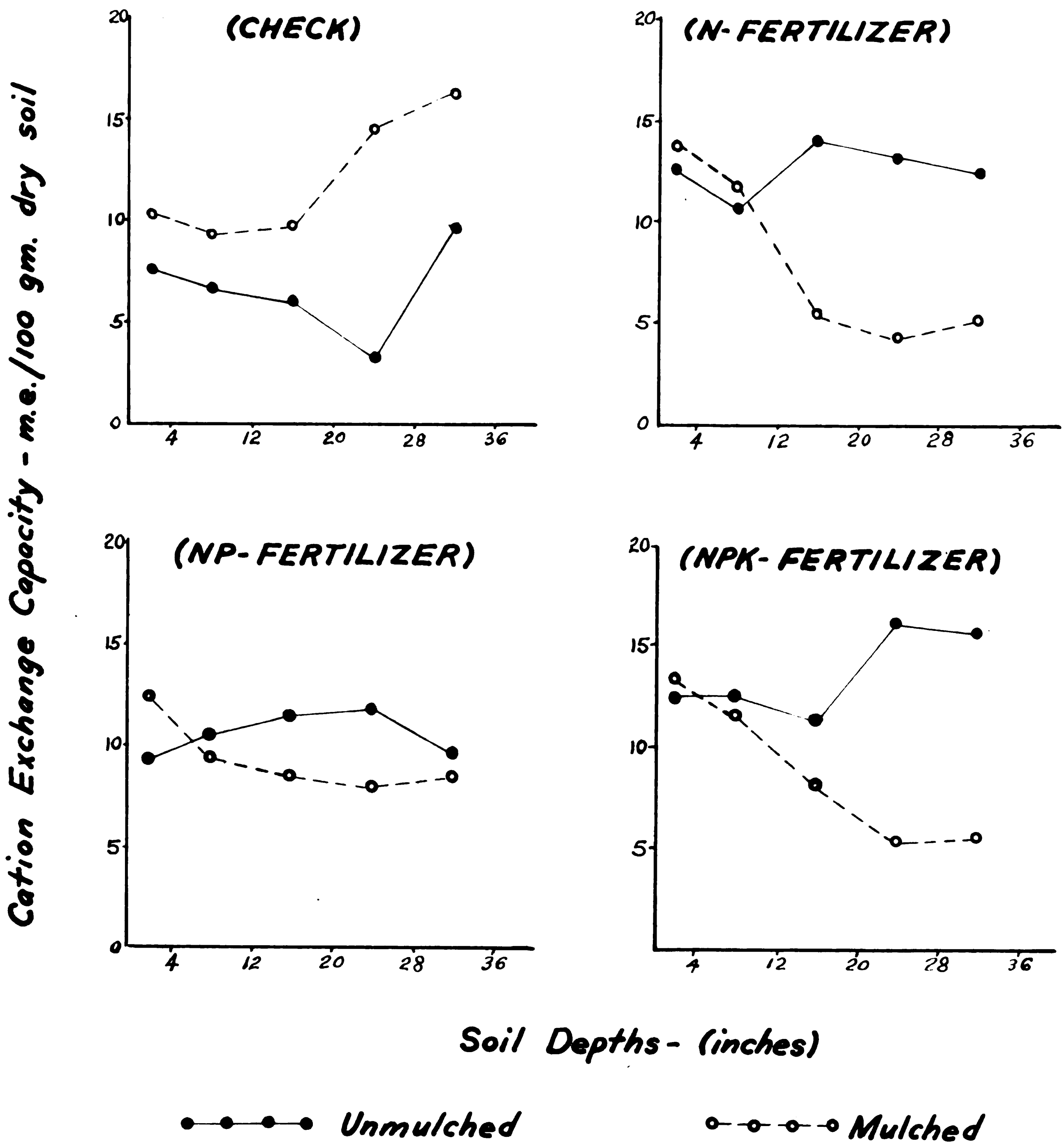
TABLE 7

CATION EXCHANGE CAPACITY AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES -- m.e./100 gm. Soil

Cultural practice	Fertilizer	Soil Depth--Inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	7.545	6.719	6.001	3.240	9.669	6.635	
	N	12.923	10.959	14.148	13.343	12.532	12.781	
	NP	9.190	10.480	11.263	11.901	9.720	10.511	
	NPK	12.394	12.467	11.416	16.112	15.801	13.640	
	Average	10.513	10.156	10.716	11.149	11.931	10.890	
Mulched	Check	10.126	9.278	9.893	14.648	16.257	12.040	9.337
	N	13.989	11.930	5.740	4.515	5.284	8.292	10.536
	NP	12.177	9.430	8.379	7.958	8.393	9.267	9.889
	NPK	13.271	11.633	8.067	5.400	5.719	8.818	11.229
	Average	12.391	10.568	8.020	8.130	8.913	9.604	
Average for depths		11.452	10.362	9.368	9.639	10.422		

	0.05	0.01
Least significant difference: Cultural practice X fertilizer	4.140	5.804

Figure 7. Cation exchange capacity at different soil depths as influenced by fertilizer application and cultural practices



Cation Exchange Capacity - m.e./100 gm. dry soil
(CHECK)
(N-FERTILIZER)
(NP-FERTILIZER)
(NPK-FERTILIZER)
0
5
10
15
20
4
12
20
28
36
Soil Depths - (inches)
Unmulched
Mulched

found most remarkable among check samples where the mulched samples had a higher exchange capacity than the unmulched samples at all depths.

Analyses of variance showed that the interaction of cultural practices with fertilizer was significant. The check samples under mulch were higher than the unmulched samples.

Per Cent Saturation with Exchangeable Calcium, Magnesium and Potassium

Values for per cent saturation of the exchange capacity with exchangeable calcium, magnesium and potassium at different soil depths as influenced by fertilizer application and cultural practices are shown in Table 8. With a lowest value of 13.94 and the highest value of 83.42 per cent saturation, the per cent saturation of the exchange capacity showed a rather broad range with an average value of 49.39 per cent. The check samples under both cultural practices had a higher per cent saturation than the samples with fertilizer treatments. A common trend was for the per cent base saturation to increase consistently as the soil depth increased.

Figure 8 shows that the per cent saturation with calcium, magnesium and potassium in check samples under mulch was higher than the mulched samples at the upper four soil depths (20-28 inches). In regard to the samples from the fertilizer

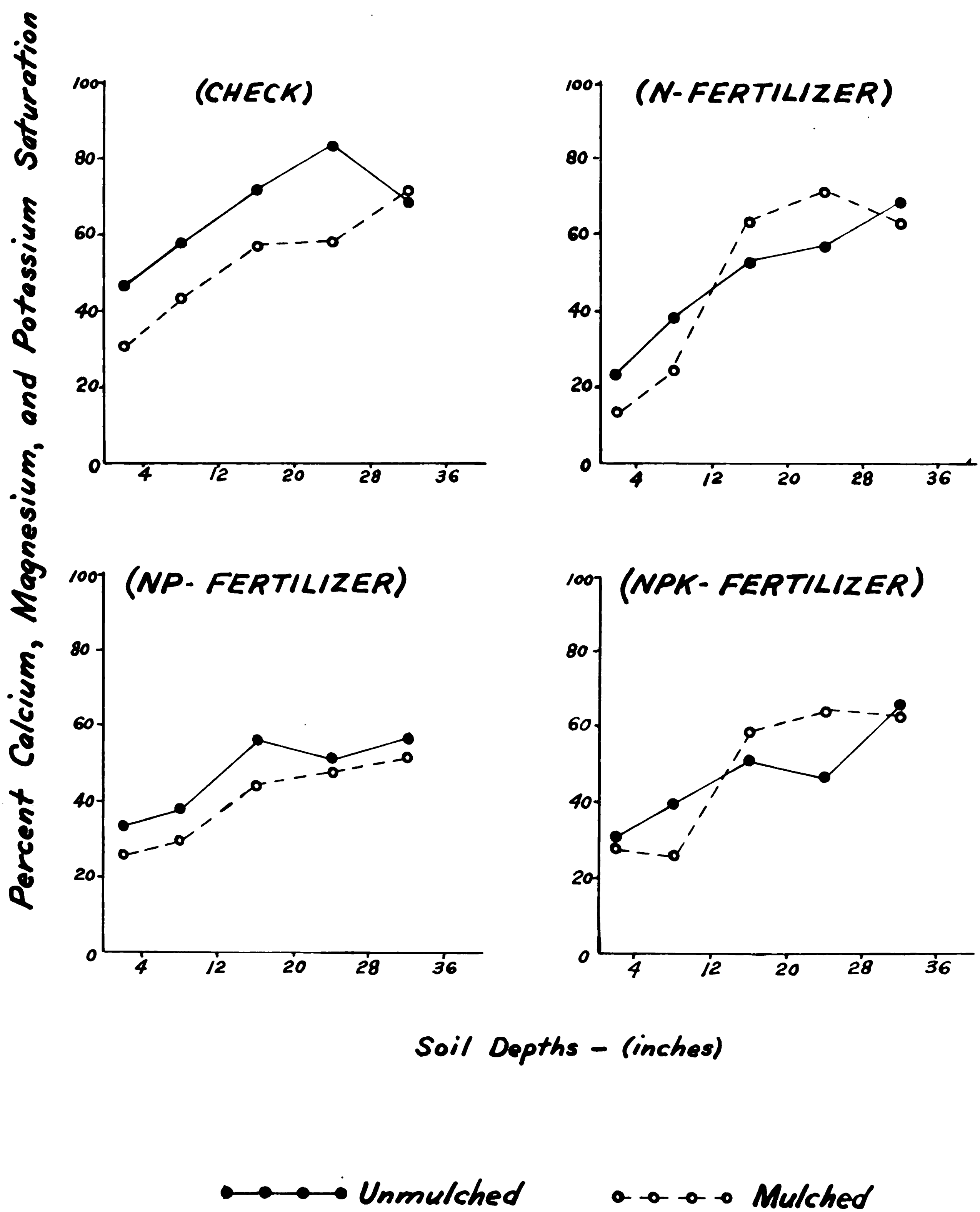
TABLE 8

PER CENT CALCIUM, MAGNESIUM AND POTASSIUM SATURATION AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES

Cultural practice		Soil Depth--Inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	47.09	58.18	71.90	83.42	69.76	66.07	
	N	23.14	38.29	52.84	56.75	68.84	47.97	
	NP	33.82	38.21	55.85	51.60	56.79	47.25	
	NPK	30.18	39.59	50.34	46.51	65.16	46.36	
	Average	33.56	43.57	57.73	59.57	65.14	51.91	
Unmulched	Check	30.95	43.29	57.40	58.97	71.18	52.36	59.22
	N	13.94	24.98	64.53	71.02	63.06	47.51	47.74
	NP	25.47	29.90	44.13	47.38	51.25	39.63	43.44
	NPK	27.47	25.58	59.15	64.74	63.30	48.05	47.21
	Average	24.46	30.94	56.30	60.53	62.20	46.89	
	Average for depths	29.01	37.26	57.02	60.05	63.67		

Least significant difference:	0.05	0.01
Between cultural practices	4.71	6.60
Between fertilizers	6.64	9.30
Between depths	7.41	10.39

Figure 8. Per cent calcium, magnesium and potassium saturation at different soil depths as influenced by fertilizer application and cultural practices.


Percent Calcium, Magnesium, and Potassium Saturation
(CHECK)
(N-FERTILIZER)
(NP- FERTILIZER)
(NPK- FERTILIZER)
0
20
40
60
80
100
4
12
20
28
36
Soil Depths – (inches)
Unmulched
Mulched

treatments, those without mulch and receiving nitrogen or complete fertilizer had a higher per cent saturation at the upper two depths (0-12 inches) and a lower per cent saturation at the three remaining lower depths (12-36 inches) than comparably mulched samples. The unmulched samples also showed a higher saturation than the mulched samples at all depths when NP-fertilizer was applied.

Analyses of variance indicated a significant difference between cultural practices and a highly significant difference between fertilizer and between soil depths. The unmulched samples were higher than the mulched samples. For the fertilizer, samples without fertilizer were higher than the samples which had received NP-fertilizer. In regard to soil depth, samples of from 12-36 inches were higher than those from the upper foot depth.

Acetate Soluble Phosphorus

The amount of acetate soluble phosphorus at different soil depths as related to the cultural practices and fertilizer is given in Table 9 and Figure 9. The lowest amount of acetate soluble phosphorus, with a value of 0.1 p.p.m., was found at the lowest soil depths (28-36 inches) of the nitrogen-mulched treatments. The highest value of 8.4 p.p.m. occurred at the first depth (0-4 inches) of the mulched samples with NPK-fertilizer application. The average of all samples under mulch was 3.0 p.p.m. and for unmulched, 3.4 p.p.m.

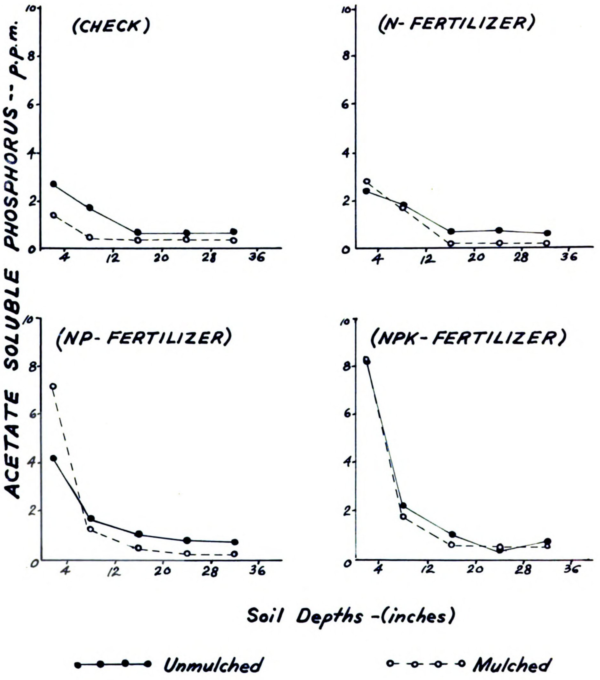
TABLE 9

ACETATE SOLUBLE PHOSPHORUS AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES -- p.p.m.

Fertilizer	Soil Depth--inches 0-4	4-12	12-20	20-28	28-36	Average
Check	2.0	1.1	0.4	0.4	0.5	0.9
N	2.6	1.7	0.4	0.4	0.3	1.1
NP	5.9	1.6	0.8	0.6	0.5	1.9
NPK	8.4	2.0	0.8	0.5	0.6	2.5
Average	4.7	1.6	0.6	0.5	0.5	

Least significant difference:	0.05	0.01
Between fertilizers	0.72	0.87
Between depths	0.70	0.98
Fertilizer X depths	1.39	1.96

Figure 9. Acetate soluble phosphorus at different soil depths as influenced by fertilizer application and cultural practices


ACETATE SOLUBLE PHOSPHORUS -- p.p.m.
(CHECK)
(N- FERTILIZER)
(NP- FERTILIZER)
(NPK- FERTILIZER)
0
2
4
6
8
10
4
12
20
28
36
Soil Depths -(inches)
Unmulched
Mulched

Analyses of variance indicated a highly significant difference between fertilizer, soil depths and for the interaction of soil depth with fertilizer. Acetate soluble phosphorus for the NPK-fertilizer sample was higher than for the sample either without fertilizer or with nitrogen, and higher for the NP-fertilizer than for the check samples. For the soil depth, samples from 0-4 inches were higher than samples from 4-36 inches. A significant increase in phosphorus was found in samples at the 0-4 inch depth, and was higher than all the remaining depths. Samples of the 4-12 inch depth, except for the check samples, were also higher in acetate soluble phosphorus than the other lower depths.

Soil pH

The pH values of five different soil depths as influenced by cultural practices and fertilizer are presented in Table 10. Samples under mulch, with the addition of nitrogen, had the lowest pH value (3.27) at the first soil depth (0-4 inches) and the highest pH (6.03) at the last soil depth (28-36 inches). The average value for all samples under no mulch was 4.64 and under mulch was 4.28.

Figure 10 shows that the pH of the samples under mulch with fertilizer was always lower at the upper depths (0-12 inches) and steadily increased at the lower depths as compared to the samples without mulch. Check samples under

TABLE 10

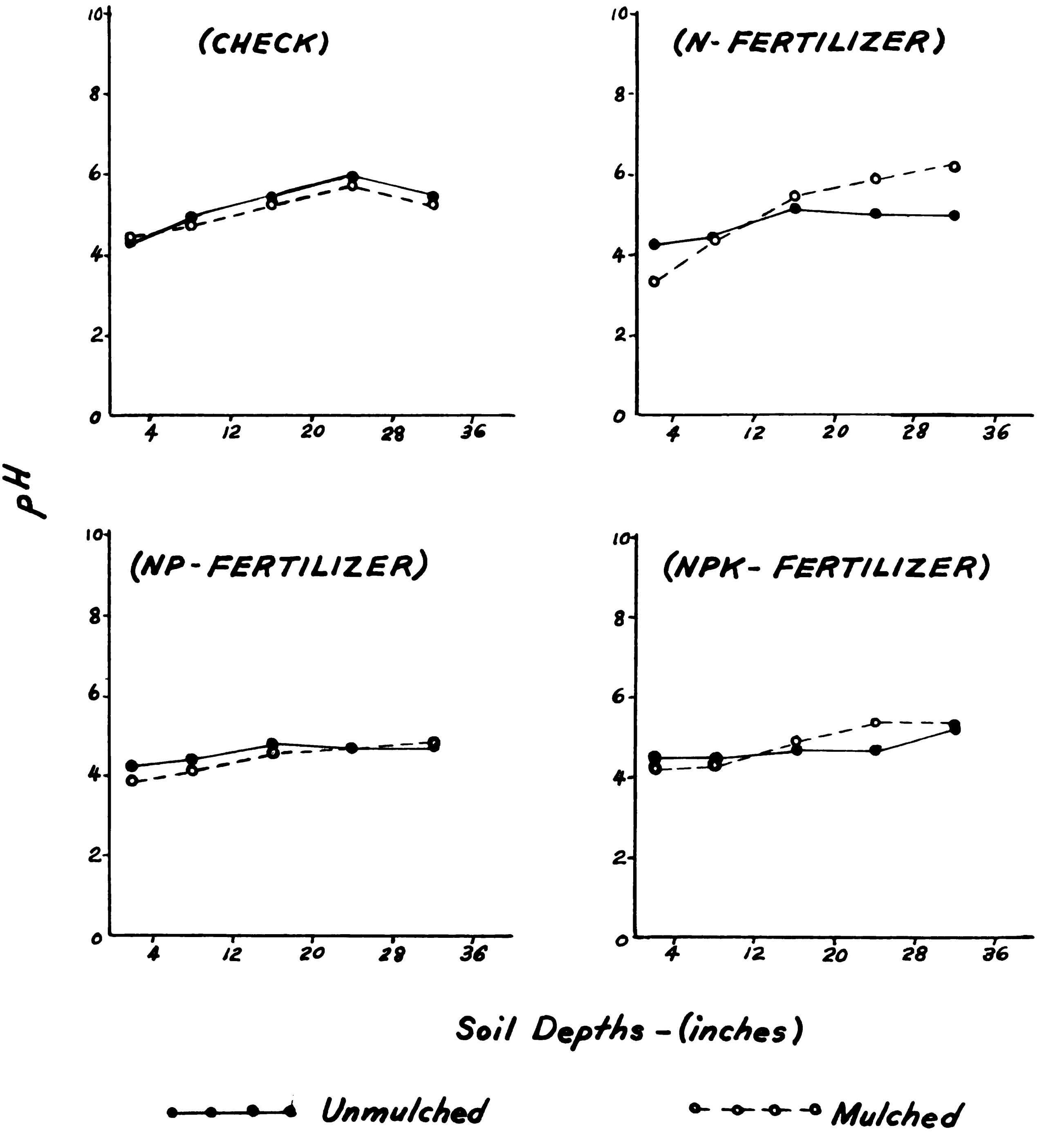
pH VALUE AT DIFFERENT SOIL DEPTHS AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES*

Cultural practice	Fertilizer	pH at Soil Depths--inches 0-4	4-12	12-20	20-28	28-36	Average	Average for fertilizers
Unmulched	Check	4.39	4.90	5.42	5.93	5.40	4.91	
	N	4.28	4.34	5.04	4.99	4.86	4.58	
	NP	4.26	4.46	4.80	4.72	4.79	4.55	
	NPK	4.49	4.45	4.63	4.59	5.12	4.61	
	Average	4.35	4.49	4.89	4.86	4.98	4.64	
Mulched	Check	4.46	4.69	5.20	5.64	5.21	4.86	4.90
	N	3.27	4.37	5.46	5.90	6.03	3.93	4.14
	NP	3.98	4.13	4.54	4.69	4.88	4.31	4.42
	NPK	4.18	4.29	4.88	5.32	5.27	4.55	4.58
	Average	3.73	4.33	4.88	5.15	5.19	4.28	
	Average for depths	3.94	4.42	4.89	4.97	5.08		

* Average pH values determined by converting to H+ ion concentration

Least Significant Difference:	0.05	0.01
Between fertilizers	0.31	0.53
Between depths	0.34	0.47

Figure 10. pH value at different soil depths as influenced by fertilizer application and cultural practices


(CHECK)
(N- FERTILIZER)
(NP - FERTILIZER)
(NPK- FERTILIZER)
pH
0
2
4
6
8
10
4
12
20
28
36
Soil Depths - (inches)
Unmulched
Mulched

mulch showed a higher pH at the first depth (0-4 inches) and a lower pH at the lower depths than the unmulched samples.

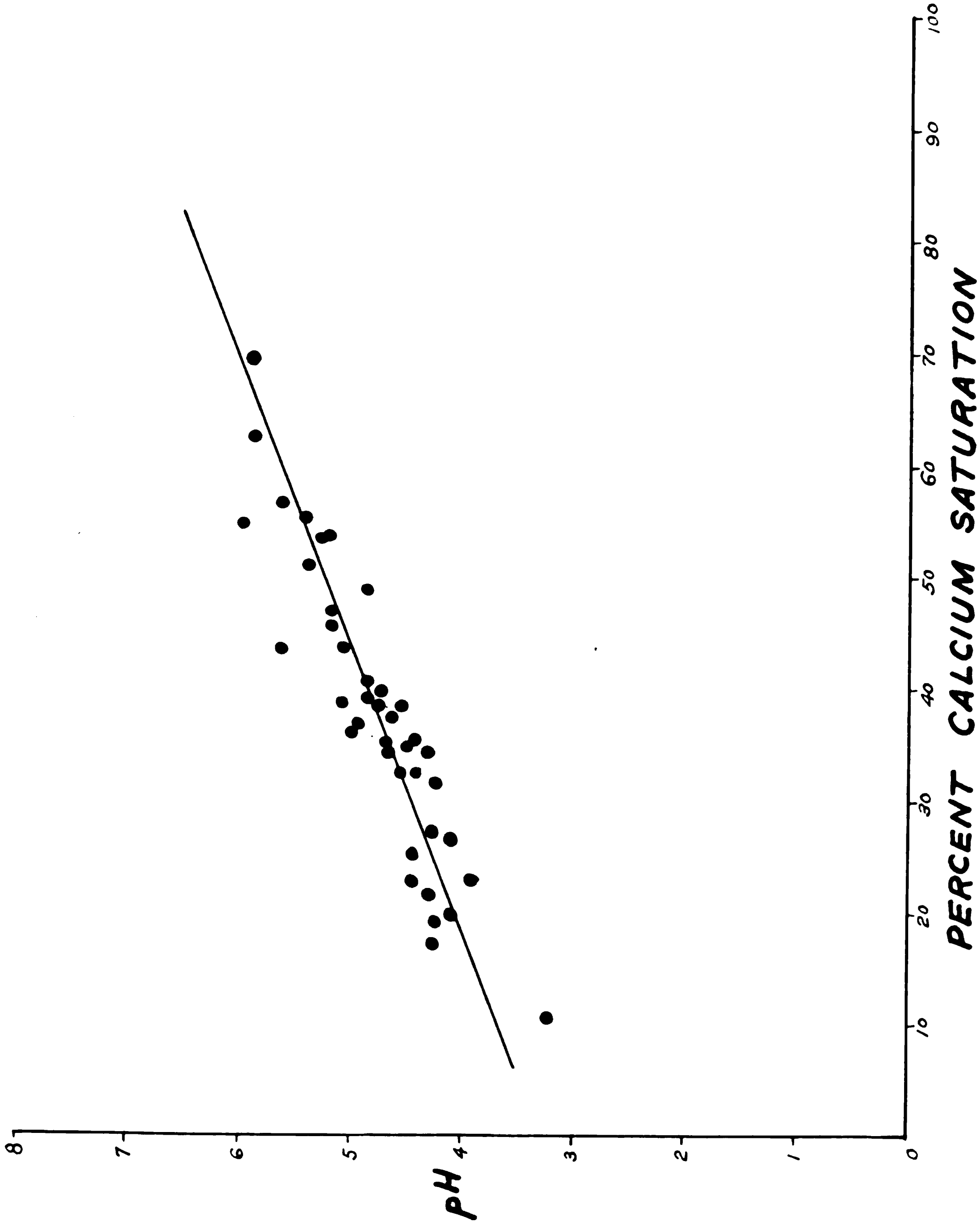
Analyses of variance indicated a highly significant difference between fertilizer treatments and between soil depths. The check sample was higher than N-fertilizer samples. For soil depths, samples taken from 28-36 inches had a higher pH than samples from 0-12 inches.

Correlation Studies

The relationship of soil pH to per cent calcium saturation; magnesium saturation; total per cent saturation with calcium, magnesium and potassium; and available phosphorus is plotted in scatter diagrams as shown in Figures 11, 12, 13 and 14, respectively. The correlation coefficient of pH value to calcium saturation was highly significant ($r = +0.92$). The correlation coefficient of pH to magnesium saturation was +0.47 and was significant. A highly significant positive correlation ($r = +0.89$) was also obtained between pH and the total saturation with calcium, magnesium and potassium. However, the highly significant correlation coefficient between pH to the available phosphorus was negative ($r = -0.86$).

Figure 11. The relationship between soil pH value and per cent calcium saturation at different soil depths as influenced by fertilizer application and cultural practices.

$r = 0.92$ $Y = 3.29 + 0.04X$



pH
0
1
2
3
4
5
6
7
8
PERCENT CALCIUM SATURATION
10
20
30
40
50
60
70
80
90
100

Figure 12. The relationship between soil pH value and per cent magnesium saturation at different soil depths as influenced by fertilizer application and cultural practices.

$r = 0.47 \qquad Y = 4.38 + 0.04X$

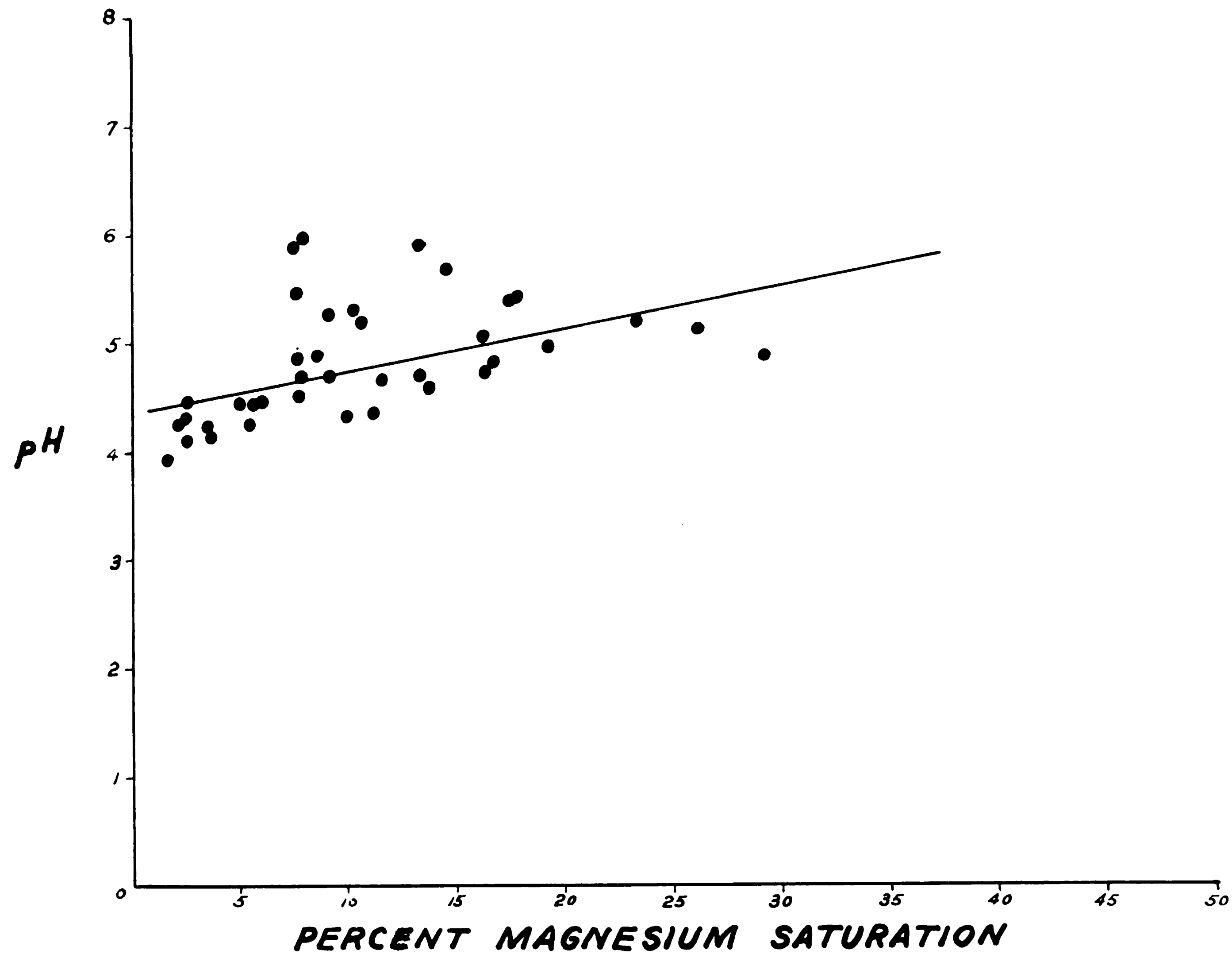

pH
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
40
45
50
PERCENT MAGNESIUM SATURATION

Figure 13. The relationship between soil pH value and per cent saturation with exchangeable cations (Ca, Mg, K) at different soil depths as influenced by fertilizer application and cultural practices.
$r = 0.89 \quad Y = 3.33 + 0.03X$

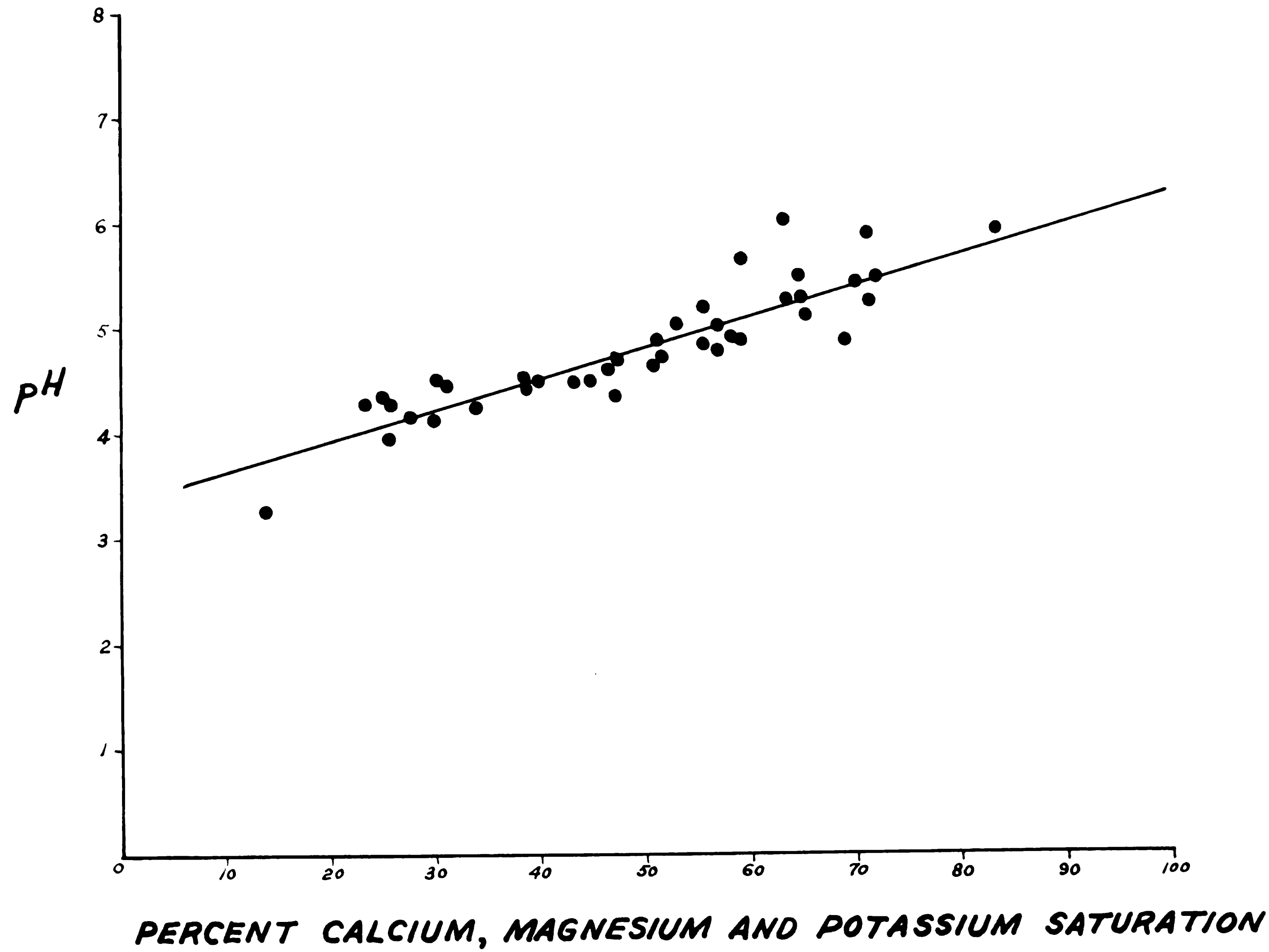
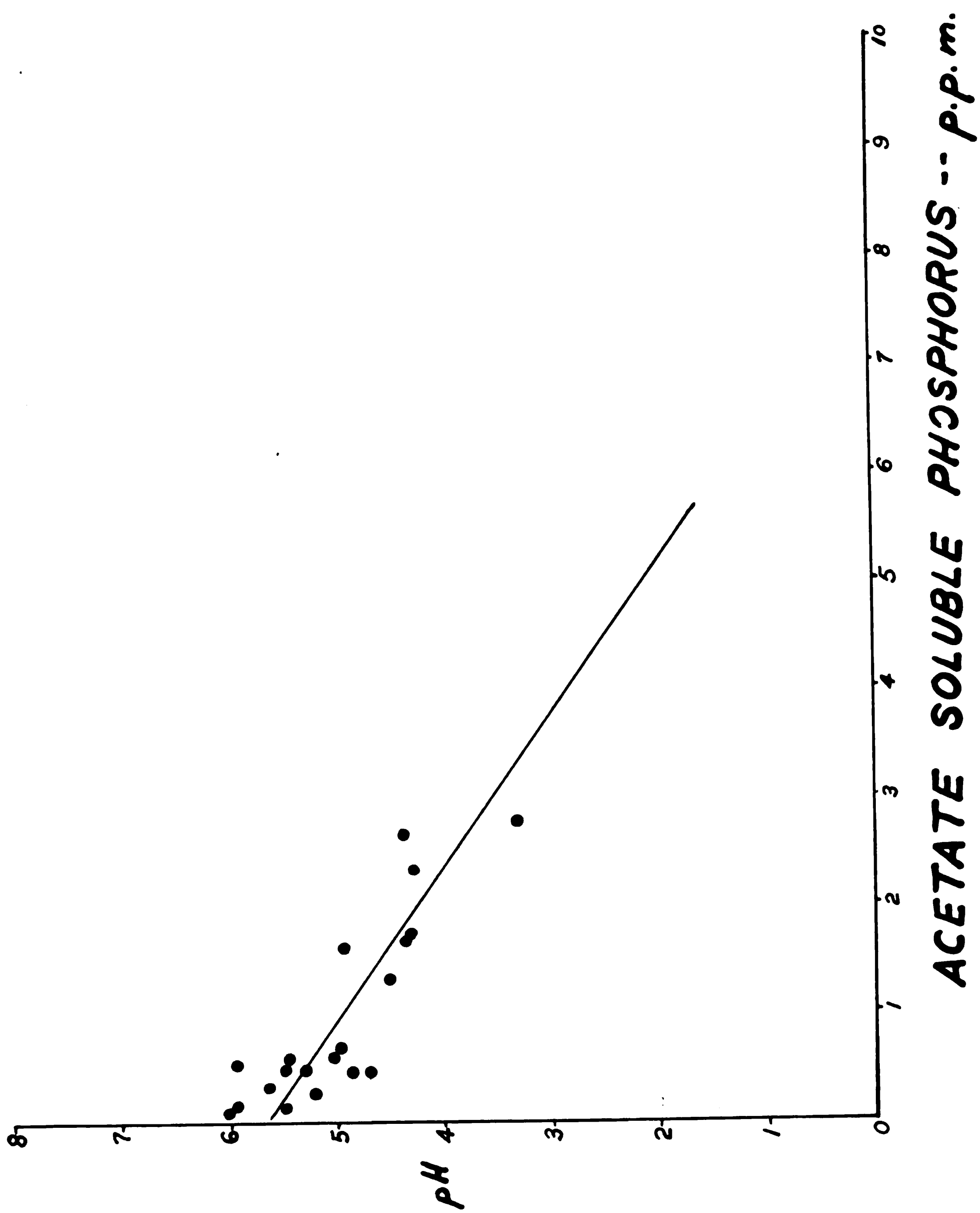

pH
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
PERCENT CALCIUM, MAGNESIUM AND POTASSIUM SATURATION

Figure 14. The relationship between soil pH value and acetate soluble phosphorus at different soil depths as influenced by fertilizer application and cultural practices.
$r = -0.86 \qquad Y = 5.65 - 0.67X$


ACETATE SOLUBLE PHOSPHORUS -- P.P.M.
0 1 2 3 4 5 6 7 8 9 10
pH
0 1 2 3 4 5 6 7 8

DISCUSSION

Mineral soil is rather complex in nature. There are a great many variations of characteristics existing in different soil horizons. According to Byers, Kellogg, Anderson and Thorp (1938), Miami silt loam soils are derived from glacial till and the B-horizon is distinctly heavier in texture than the A-horizon. Kellogg and Orvedal (1951) pointed out that these soils are leached, acid, and have relatively low availability of most plant nutrients. They are also rather low in organic matter. However, they are highly responsive to management. Since the conditions of these soils are known, addition of adequate fertilizer and lime should correct the inherent shortages of the soil and result in higher productivity.

Effect of Mulch upon Exchangeable Calcium in Soil Samples

Soil reaction is one of the principal factors influencing leaching and fixation of many nutrient elements in soils (Peech 1941). The exchangeable calcium and magnesium are expected to be more abundant in the lower depths than in the surface soil as was found in this investigation. Goodman (1953) postulated that the migration of exchangeable calcium from the immediate soil surface under the hay mulch was due to the action of one or more acids formed in the decomposition of the hay mulch. Thus, the resulting effect would be dependent on the nature of the mulch material used. A comparison of the pH values of the check samples, mulched and unmulched, shows that the first soil depth (0-4 inches) immediately under mulch had a slightly higher pH value (4.46) than the unmulched samples with pH 4.39 (Table 10). Thus, the mineralization of grass hay would not appear to be effective in promoting the movement of calcium from the surface to the deeper soil layers. This is in agreement with Wander and Gourley (1943), Weeks, Smith and Mack (1950) who found that mulching increased the amount of exchangeable calcium as compared with cultivation in an apple orchard. The results of this investigation showed that the check samples under mulch had a higher per cent calcium saturation at the first soil depth (Figure 2) and the total amount of exchangeable calcium in five soil depths was one-third more than that from the unmulched soil.

There was a reduction of exchangeable calcium in the upper soil depths under mulch with an addition of fertilizer, particularly in the form of ammonium nitrate with phosphorus and potash (Figure 2). Merkle (1928) reporting on his experiment in Hagerstown silt loam stated that those plots receiving ammonium sulfate with phosphorus and potash or receiving dried blood with phosphorus and potash showed a reduction of exchangeable calcium. This reduction may have been due to two factors: (1) the leaching action as a result of adding acid forming ammonium salts in the soil; or (2) the depletion of a greater quantity of exchangeable calcium by the fruit tree as a result of better growth under mulch. The leaching effect was more severe under mulch condition (Figure 2 and Figure 14) and may have been an indirect effect of an accelerated mineralization because of better moisture under mulch. The possibility of additional tree growth depleting greater quantities of exchangeable calcium is illustrated by the results shown in Table 11 and Figure 15.

Effect of Mulch upon Exchangeable Magnesium in Soil Samples

The behavior of exchangeable magnesium was very similar to that of calcium. Magnesium, however, may be more subjected to the phenomenon of "forced" migration because of its position in the lyotropic series. A comparison of magnesium content of the soil with the yield or circumference of the trees under mulch and unmulched (Figure 15), indicates that, besides leaching, the severe reduction of magnesium may have been a result of absorption by the trees in a greater amount to support their higher yield and better growth under mulch.

Weeks, Tyson and Drake (1950) stated that the exchangeable magnesium was increased at the lower soil depths (6-12 and 12-18 inches) under the low grade hay mulch in a bearing apple orchard. The results of the check samples in this investigation showed an agreement with their findings. It is

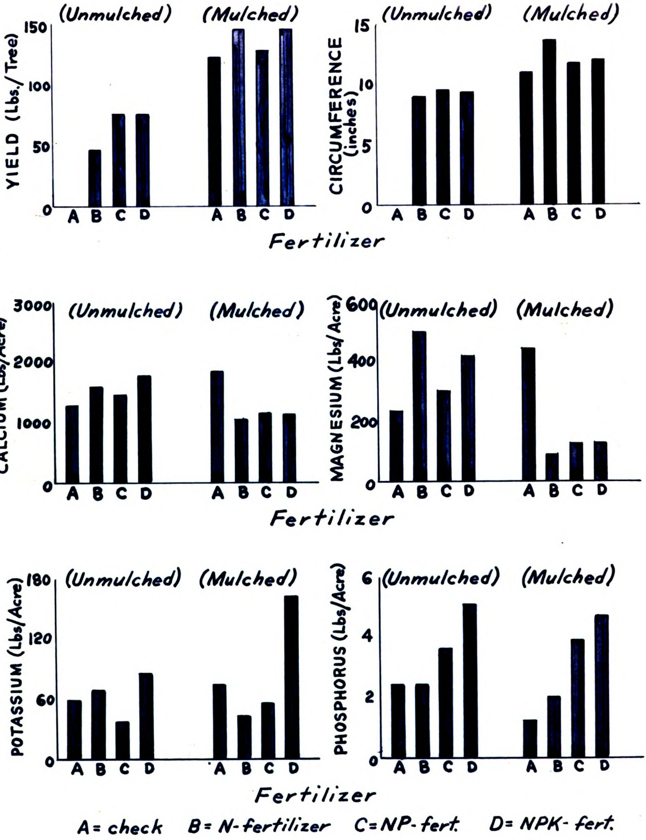
TABLE 11

THE RELATION OF YIELD AND CIRCUMFERENCE OF PEACH TREES TO THE AMOUNT OF EXCHANGEABLE CALCIUM, MAGNESIUM AND POTASSIUM IN SOIL AS INFLUENCED BY FERTILIZER APPLICATION AND CULTURAL PRACTICES*

Fertilizer	lbs./tree	Trunk circum-ference--ins.	Exchangeable Calcium lbs./acre	Exchangeable Magnesium lbs./acre	Exchangeable Potassium lbs./acre	Acetate sol. phosphorus lbs./acre
			Unmulched Trees			
Check	---	---	1259.5	236.8	59.3	2.4
N	46.00	9.00	1596.0	497.4	69.1	2.4
NP	77.00	9.50	1480.3	300.5	37.3	3.6
NPK	77.00	9.75	1789.0	421.6	84.9	5.1
			Mulched Trees			
Check	122.00	11.00	1866.1	442.9	74.4	1.2
N	147.00	13.75	1026.7	91.8	44.0	2.0
NP	129.00	11.75	1173.1	131.6	57.7	3.9
NPK	147.00	12.00	1151.8	131.7	162.4	4.7

*Soil analyses--average for 0-36 inches. Pounds per acre calculated on basis of 2,000,000 pounds of soil per acre

Figure 15. Relation of yield and circumference of peach trees to the amount of exchangeable calcium, magnesium, potassium and acetate soluble phosphorus in soil as influenced by fertilizer application and cultural practices. (Pounds per acre, calculated on the basis of 2,000,000 pounds of soil per acre).


(Unmulched)
(Mulched)
YIELD (Lbs./Tree)
150
100
50
0
CIRCUMFERENCE (inches)
15
10
5
0
A B C D
A B C D
Fertilizer
CALCIUM (Lbs/Acre)
3000
2000
1000
0
MAGNESIUM (Lbs/Acre)
600
400
200
0
Fertilizer
POTASSIUM (Lbs/Acre)
180
120
60
0
PHOSPHORUS (Lbs/Acre)
6
4
2
0
Fertilizer
A= check
B= N-fertilizer
C=NP-fert.
D= NPK-fert.

interesting to note that the exchangeable magnesium was higher under mulch than unmulched at the surface depth (0-4 inches) when NP or NPK-fertilizer was added. However, this was not true with the addition of nitrogen fertilizer alone. Such findings indicate that phosphorus might have a certain effect on the soil colloid and increase the adsorptive surface for magnesium or the phosphorus may have combined directly with magnesium. Either or both factors would tend to increase exchangeable magnesium.

Effect of Mulch upon Exchangeable Potassium in Soil Samples

According to Bregger and Musser (1939), Wander and Gourley (1937, 1938), Boller and Stephenson (1946) and Drake (1950), exchangeable potassium was increased in deeper soil layers under mulch than with cultivation. The result obtained from the check samples under mulch in this investigation indicated that exchangeable potassium was increased and penetrated deeper into the soil than in the unmulched samples. This probably was associated with a more uniform supply of soil moisture that, in turn, would reduce the fixation of potassium and promote its migration into the soil.

The data in Table 5 showed that the potassium was higher at the first two depths (0-12 inches) under mulch than unmulched when nitrogen (N) or nitrogen with phosphorus (NP) was used as fertilizer. Samples from under mulch with addition of a complete fertilizer (NPK) showed a much higher level of potassium than the unmulched samples at all depths. It would seem that the upper two soil depths (0-12 inches) had a much higher adsorptive power for potassium under mulch. According to Albrecht (1943), potassium is adsorbed on the colloidal surface in a mobile form. Therefore, the increase of exchangeable potassium under mulch with N and NP-fertilizers may have been the result of mineralization of the mulch material. As soon as the mulch material decomposed, and increase of potassium in the soil would be expected. The increase of adsorbed potassium on the colloid surface would continue and any "excess" of this element should migrate into the deeper soil layers as was evident when NPK-fertilizers were applied. Merkle (1928), Wilson (1930), Murphy (1934) and Hoover (1944) stated that potassium may accumulate in the A horizon in replaceable form when applied in excess of plant needs. Mulching would appear to reduce such an accumulation.

Effect of Mulch upon Exchange Capacity of Soil Samples

Figure 7 indicated that the exchange capacity of soil was much higher for the mulch than for the unmulched samples on unfertilized plots. These data are in agreement with Reuther (1941) who found that mulch appeared to have increased the exchange capacity of the soil slightly when compared to sod or cultivation in McIntosh apple orchards. However, in this investigation, samples under mulch with the addition of fertilizer showed higher exchange capacity than the unmulched samples only in the surface soil. Such a result may be explained, as Albrecht (1941) stated, by the high ion adsorption and ion exchange, as physical and chemical processes, of organic matter. The decomposition of the mulch material may have induced the migration of certain organic colloids into the soil and thus increase the exchange capacity.

Effect of Mulch upon Acetate Soluble Phosphorus in Soil Samples

Figure 9 indicated that acetate soluble phosphorus was higher in the surface soil than at lower depths for every comparison. There was no significant effect of mulch upon the vertical movement of acetate soluble phosphorus. These results showed agreement with Boller and Stephenson (1946). However, they did not agree with the study of Weeks, Tyson and Drake (1950). The reduction in acetate soluble phosphorus under a mulch with no fertilizer or nitrogen (N) may be associated with greater tree growth (Figure 15).

Soil pH

Turk and Partridge (1947) stated that there was a definite decrease in the pH in Miami soil with alfalfa and straw mulches which had received ammonium sulfate. The results of this study showed that the mulched samples with nitrogen fertilizer always had a lower pH at the first depth as compared with the unmulched samples. This is apparently in agreement with the results obtained by Turk and Partridge. The decrease in pH may have resulted from the release of certain organic acids in the process of decomposition of the mulch.

SUMMARY AND CONCLUSIONS

The relation of cultural practices and fertilizer (N, NP, or NPK) application to the exchangeable calcium, magnesium, potassium, exchange capacity, acetate soluble phosphorus and soil pH at five depths of a Miami silt loam was studied.

The amount of exchangeable calcium under mulch with fertilizer was lower than unmulched at all corresponding depths. The lowest quantity of calcium occurred at the 0-4 inch soil depth under mulch when nitrogen fertilizer was applied. The per cent calcium saturation under mulch receiving fertilizer was steadily increased as the soil depth increased.

Exchangeable magnesium was definitely lower in quantity under mulch which had received only nitrogen. When no fertilizer was applied, the mulched samples showed a higher quantity of exchangeable magnesium than samples from unmulched plots. The per cent magnesium saturation under mulch with addition of fertilizer was also lower than samples under no mulch.

The amount of exchangeable potassium was higher at 0-12 inches depth when N-or NP-fertilizer was applied, and very much higher at all depths when NPK-fertilizer was applied with mulch than without mulch. However, it was lower in quantity at 0-12 inches when under mulch without fertilizer application as compared with the unmulched samples. The total amount of exchangeable potassium was higher for the mulched samples than for the unmulched samples, except for those with addition of nitrogen.

A higher cation exchange capacity was found under mulch than with the unmulched samples when no fertilizer was applied. The first soil depth (0-4 inches) was also higher in exchange capacity under mulch with addition of fertilizer. The per cent calcium, magnesium and potassium saturation was higher for the samples under no mulch than for the mulched samples. With applications of fertilizer, the base saturation at 0-12 inches was higher under mulch.

There was a greater amount of acetate soluble phosphorus from unmulched than from mulched soils when no fertilizer was applied. An increase, however, was obtained at the first soil depth (0-4 inches) under mulch with fertilizer when compared to the unmulched samples.

The pH value of the surface soil (0-4 inches) under mulch with no fertilizer application was slightly increased. When fertilizer had been added the pH value at the surface soil was decreased under mulch.

There was a significant correlation of pH with per cent magnesium saturation, and a highly significant correlation of pH with per cent calcium saturation and with the total per cent saturation with calcium, magnesium and potassium. A negative correlation of pH to acetate soluble phosphorus was also highly significant.

The result of soil analysis in this investigation indicated that mulching influenced the nutritional status in the soil. In order to obtain the full advantage of a complete fertilizer in an orchard on Miami silt loam an adequate mulching program should be used. The analysis of the soil also indicates the need for additions of dolomitic lime.

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