NUTRIENT DEFICIENCY IN THE A_1, A_2, AND B HORIZONS OF SOME COMMON MICHIGAN SOIL TYPES

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OUTLINE

INTRODUCTION

The causes for the unproductiveness of the horizons of soil below the more weathered A_1 horizon have been the subject of investigation for many years. In common parlance has come the term "rawness" of subsoil, pertaining to the unproductivity of soils taken from below the plowed layer. This term immediately brings into consideration two indefinite quantities which must be qualified as to meaning. At present it is generally conceded that a thrifty growth of plants, at least comparable to that occurring on the corresponding surface horizon, would be required on the lower soil horizons to demonstrate that no "rawness" exists in them. It is evident, therefore, that the meaning of the term "rawness" must vary with different soil types. The term "subsoil" generally refers to that portion of soil below the plowed layer. Since this term is indefinite and as it fails to recognize specific horizons in the soil profile, it will be used in this paper only in citing references to literature. The subsurface horizons of a single soil type and of different soil types normally vary in the depth at which they occur. It is, therefore, evident that data obtained from different soils taken at specific depths may not correlate.

"Rawness" of subsoils has been attributed to several causes, some of which are: (1) deficiency of available nutrients, (2) curtailed biological activity, (3) presence of toxic substances, (4) unfavorable soil reaction, (5) lack of aeration at the greater depths. Insufficient evidence to definitely establish any one of these factors as the cause for poor plant growth on subsurface horizons prompted the present study.

REVIEW OF LITERATURE

Hilgard (12) stated that "rawness" did not exist in soils of arid regions, in contrast to the general knowledge of unproductivity of the subsoils of humid regions. He observed that, in general, the subsoils of humid regions were lower in organic matter content and more retentive of moisture and plant nutrients than the corresponding surface soils. He attributed "rawness" to the more compact subsoil and to the lack of organic matter with the corresponding deficiency of the weathering agents, carbonic and "humic" acids. Hilgard suggested that this condition is the result of the washing down of the finer particles of soil to a depth where they are deposited and form a more or less impermeable layer which inhibits aeration and reduces the number of beneficial microorganisms, thus leading to unfavorable reduction processes and the formation of toxic substances.

Hall (10) recognized unproductivity in soils in humid regions, below the plowed layer, and warned against bringing up more than a half inch of soil below the "plow sole" in a single year. He suggested that the scarcity of the microbiological population below the plowed layer may be responsible for the sterility of the soil.

Fraps (9) stated that in humid regions, the subsoils are not suited to plant growth and further that the difference in this respect between arid and humid soils is due to the greater depth of penetration of air and the roots of plants in the arid soils.

Alway, McDole, and Rost (3) presented evidence to show that subsoils of certain humid regions exhibit "rawness" to non-leguminous crops; but with inoculated legumes, soils taken from 15 to 20 feet below the surface support as good a growth as their corresponding surface soils. These soils, when supplied with nitrogenous fertilizer, may not exhibit "rawness" even to non-leguminous crops. They accepted Hilgard's views without question, and Alway and McDole (2) distinguished between arid and humid regions as follows:

"a humid region is one in which the precipitation exceeds the evaporation. An arid region is one in which the precipitation is less than the evaporation from a free water surface".

Lipman (16) stated that arid subsoils are as unproductive of non-legumes as are those of humid regions, and questioned the idea that inoculated legumes will not grow as well on any subsoil as on its corresponding surface soil.

Alway (1) asked for more information on the subject and stated that the idea that arid subsoils are not as unproductive as the subsoils of humid regions is based largely on the personal observation of the late Dr. E. W. Hilgard.

Harmer (11) presented data to show that certain subsoils are unproductive even to inoculated legumes, and stated that the impaired growth is not associated with either deficiency of nitrogen or low carbonate content of the soil.

McMiller (18), using two of Harmer's (11) soils, concluded that unproductiveness could be overcome by supplying sufficient amounts of available phosphorus and potassium.

Weaver, Jean, and Crist (25), and Crist and Weaver (8) showed that plants may absorb applied available nutrients from subsoils. The former also concluded that soil from the lower depths is suited to plant growth even though the average depth of root penetration of small grains at the Colorado station is but one and three-tenths feet.

Millar (19), working with corn plants, found that: "If the amount of growth be taken as a measure of the availability of nutrients of the horizons studied, it must be concluded that the corn plant draws very sparingly on the soil horizons below the surface".

Millar (20) found inoculated alfalfa plants to be capable of growth even after the surface roots had been excluded from the surface soil by means of glass cylinders. He also found (21) that the lower roots of plants are capable of absorbing nutrients from the soils, if the nutrients are available, and that poor growth in certain horizons of Hillsdale loam in the greenhouse was due to deficiencies of nitrogen and phosphorus.

Conner (7) found nitrogen and phosphorus to be the limiting factors for plant growth on all subsoils studied, as compared to their respective surface soils. Potassium and lime were found to be deficiant to a less degree in the subsoil than either nitrogen or phosphorus. He further concluded that nitrogen and phosphorus were more essential to the first crop than to the second, and ascribed this to a greater availability of the nutrients in the soil after standing for the year in the greenhouse.

EXPERIMENTAL

Description of the Soil Used

The soils for this study were taken from representative areas in close proximity to East Lansing, Michigan. The soils, therefore, were developed under similar conditions of temperature and rainfall. Four soil types were selected which are widely distributed throughout the State.

The Hillsdale soil is the heavier phase of Hillsdale. The plow soil is a grey-brown granular loam, underlain by a much lighter colored yellowish-brown loam, beneath which is found a darker colored brown sandy loam.

The Conover silt loam is a greyish-brown silt loam to a depth of about 8 inches, underlain with a yellowish-grey loam which grades into a mottled, yellowish brownish-grey, friable, sandy clay loam.

The Miami silt loam presents a light greyish-brown silt loam surface or plow section, directly underlain by a dull yellowish-brown, thin layer of clay loam, beneath which is found a very compact reddish-brown clay loam.

The Bellefontaine sandy gravelly loam consists of a brown sandy gravelly loam surface, underlain with a horizon of light yellowish sandy loam, which grades into a reddish-brown layer of sand, gravel and clay mixture.

Method of Obtaining Soil Samples

By means of a recent soil map of this region (1932) large areas of the soil types were located. A location which was level and deemed representative of the entire area was chosen for the sampling. All of these areas were in sod at the time of sampling, although all had been plowed at some previous time. In every case, the A_1 horizon is the plowed layer. The second horizon is the A_2 or leached horizon, and the third horizon in depth is the B horizon.

The surface debris was scraped back and the first sample was taken, then to make sure that no soil was taken from the areas of gradation, between the horizons, a layer of soil was removed before taking the next horizon. Each horizon was distinctly different in color, and no difficulty was encountered in differentiating between them. The depth of sampling, moisture equivalent, and mechanical analysis are shown in Table 1. The depth at which the samples were taken shows that the A_2 and B horizons of the various soil types occur at different depths.

About four hundred pounds of soil was taken from each horizon sampled. These samples were carried into the greenhouse, each one screened, air dried, thoroughly mixed, and stored until needed. The portions of the soil

Table 1. Moisture equivalent, and mechanical analysis of the soils.

Soil Type	Horizon	Depth of Sampling	Moisture Equivalent	Total Sand Percent	Convention Silt Percent	Convention Clay Percent	Total Colloid Percent
		Inches					
Miami Silt Loam	A_1	2-5	19.6	42	30	28	40
	A_2	6.5-9	19.2	54	16	30	40
	B	10-15	27.2	34	20	46	56
Hillsdale Sandy Loam	A_1	2-6	16.8	61	22.4	16.6	23.6
	A_2	14-22	15.2	59.6	18.8	21.6	27.4
	B	24-32	13.1	59.6	21.6	18.8	26.0
Bellefontaine Sandy Loam	A_1	2-5	9.15	76	9	15	17
	A_2	7-13	7.9	83	8.5	8.5	12
	B	15-23	13.5	80	11	9	12
Conover Silt Loam	A_1	2-7	25.8	60	21	19	26
	A_2	9-15	29.4	60	20	20	28
	B	17-35	23.9	56	21	23	30

for laboratory work were crushed in a mortar to pass through a 2 mm. screen, and stored in two-quart sealed jars.

Methods

The soil reaction was determined electrometrically, using the quinhydrone electrode against the normal calomel cell. A mechanical analysis of the soils was made, using the hydrometer method of Bouyoucos (5). Total nitrogen was determined by the Kejhdal method. The moisture content of the soils on which chemical determinations were being made was maintained at the moisture equivalent as determined by the method of Bouyoucos (4).

It was desired to raise each soil to the same level with respect to soluble phosphorus, as determined by the Truog (23) laboratory method, and to the same level of readily soluble potassium, as extracted by Spurway's (22) recommended acetic acid solution for easily soluble nutrients. The potassium in the soil was extracted with a 1:1 ratio of 0.015 N acetic acid and soil. The dilute solution of acetic acid flocculates the soil, and therefore enables one to obtain a clear extract, which would be impossible in many cases with distilled water. The soil and the dilute acid were shaken together 30 minutes. The extract was then obtained by filtering through a fine filter until it came through clear. The potassium in the extract was determined by a modification of the Kramer-Tisdall (15) method. The method used in the determinations was as follows: 2 cc. of the filtrate was transferred to a 15 cc. centrifuge tube. Six drops of Kramer-Tisdall cobaltinitrite solution was added with shaking, then 2 cc. of pure 95% ethyl alcohol, which precipitates the potassium. The tubes were then stoppered and allowed to stand for at least 15 minutes to insure complete precipitation of the potassium. The sides of the tubes were washed down with 1 cc. of 50% alcohol, and the tubes were then centrifuged for 45 minutes. If the tubes are perfectly clean, the precipitate will collect at the bottom with very little adhering to the sides. At the end of the centrifuging period, the supernatant liquid was gently poured off and the tubes were allowed to drain while inverted. The precipitate was next suspended in 2 cc. of alcohol by the use of a glass stirring rod which was then washed with a few drops of the alcohol. The tubes were centrifuged again for a period of 15 minutes. At the end of this time, the liquid was poured off and the precipitate was allowed to dry with the tubes inverted. It is necessary that the precipitate be perfectly dry before titration.

The titration was carried out by adding in excess a .02 N potassium permanganate solution, followed by approximately 1 cc. of 4 N sulphuric acid. The precipitate was mixed thoroughly with the fluid by means of a glass rod. The tube was then immersed in a hot water bath (85-90° C) only long enough to heat the solution and then back-titrated with .01 sodium oxalate to the point where decolorization occurred. If an excess of oxalate was added, it was back-titrated with the potassium permanganate. One cc. of .01 N permanganate is equivalent to 0.071 mg. of K.

The nitrate supply in the soil used in greenhouse culture was determined at intervals during growth of the plants. Due to the large number of tests required, a very rapid method was devised. The upper chamber of a La Motte glazed porcelain soil reaction testing block was half filled with soil and four or five drops of .015 N acetic acid solution was added to wet the soil and extract the nitrates. One drop of the solution was then allowed to run down the trough into the lower chamber, where it was treated with three drops of a diphenylamine-sulphuric acid solution. This solution was made up according to Spurway (22).

Laboratory Procedure

The data in Table 2 show the soil reaction, total nitrogen, and easily soluble potassium and phosphorus of the soils. The pH values of the horizons vary as much as .5 unit in the same profile, while the values for different soil types vary even more. This data is at variance with the work of Thornton (23) who averaged a number of determinations, irrespective of soil type, and concluded that the pH of subsoils and surface soils was practically identical. It is evident that the average from such a large group of soils would obscure any differences of the individual soils. The data in Table 2 show that total nitrogen is much higher in the surface soils than in the subsurface horizons; also that in the Hillsdale and Bellefontaine types, the two lighter soil types of the group, the total nitrogen was greater in the B horizon than in the A_2 or leached horizon. With the Conover and Miami types, the total nitrogen decreased with the depth of the horizon. Except in the case of the Hillsdale type, the quantity of soluble phosphorus in the A_2 and B horizons was as great as or greater than the quantity in the surface horizon. The soluble potassium decreased with the depth of the horizon, except in the case of the Conover in which the soluble potassium was low with but little variation in the different horizons.

It was desired to raise each of the soils to the same level with respect to readily soluble phosphorus. One hundred pounds was chosen from Truog's (24) recommendations as the level to which the soil in the greenhouse cultures would be raised. In order to determine the quantity of superphosphate to be applied to have one hundred pounds of readily soluble phosphorus in the soil, 100 gram portions of the soil were treated with increments of mono-calcium phosphate, ranging from the equivalent of 100 to 4000 pounds of 20 percent superphosphate per acre. These soils were made up to the moisture

Table 2. The pH, organic matter content, total nitrogen, soluble phosphorus and potassium contents of the untreated soils.

Soil Type	Horizon	pH	Total Nitrogen Percent	Soluble Phosphorus Pounds Per Acre	Soluble Potassium Pounds Per Acre
Miami	A_1	5.53	.095	34.8	21.07
Silt	A_2	5.06	.056	18.1	20.2
Loam	B	5.11	.040	15.4	25.6
Hillsdale	A_1	6.45	.128	42.4	35.6
Sandy	A_2	7.04	.027	20.7	24.0
Loam	B	6.85	.032	15.2	20.2
Bellefontaine	A_1	7.45	.056	26.8	16.28
Sandy	A_2	7.23	.018	12.5	24.09
Loam	B	7.93	.028	7.7	50.8
Conover	A_1	6.65	.219	8.9	135.2
Silt	A_2	6.78	.076	6.2	189.0
Loam	B	7.3	.047	14.3	297.6

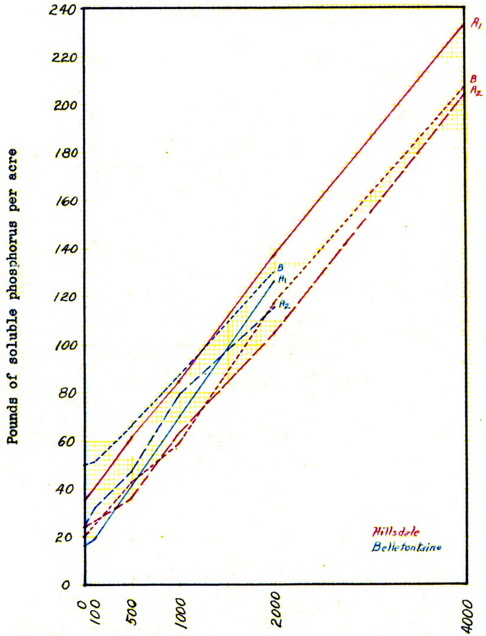
equivalent as determined by the Bouyoucos method. After standing for eight days in covered tumblers to prevent evaporation, the readily soluble phosphorus was determined. The data are reported in Table 3 and are presented graphically in Figures 1 and 2. From the graphs, the amount of mono-calcium phosphate necessary to raise the soluble phosphorus to 100 pounds per acre was interpolated. The equivalents of 20 percent superphosphate necessary to raise the soluble phosphorus to 100 pounds per acre are also given in Table 3.

For the purpose of this experiment, an arbitrary point of 100 pounds per acre of readily soluble potassium was taken as the basis for the potassium application. This quantity is equivalent to the concentration at which Hoagland and Martin (14) obtained their maximum crop yield; and the total quantity added to raise the soluble potassium content of the soil to this level was not greater, except in two or three cases, than that at which Hoagland and Martin observed a decrease in yield on the soil described. It was assumed, therefore, that no toxic affect would be produced as a result of excessive applications of potassium chloride to increase the soluble potassium to 100 pounds per acre. Increments of potassium chloride, ranging from 500 to 4000 pounds per acre, were applied in solution to 100 gr. samples of the soils. These samples were treated the same as those for phosphorus determinations, except that they were allowed to stand but five days before extraction for soluble potassium. The data showing the quantity of potassium soluble in the soil after the applications of KCl are presented in Table 4. From this data curves (Figures 3 and 4) were constructed which were used to determine the quantity of potassium chloride necessary to raise the soluble potassium content to the 100 pound level. The equivalents of 50 percent muriate of potash necessary to raise the level of soluble potassium to 100 pounds per acre are also givenin Table 4.

Table 3. Rate of application of phosphorus and resultant quantities of readily soluble phosphorus in soils.

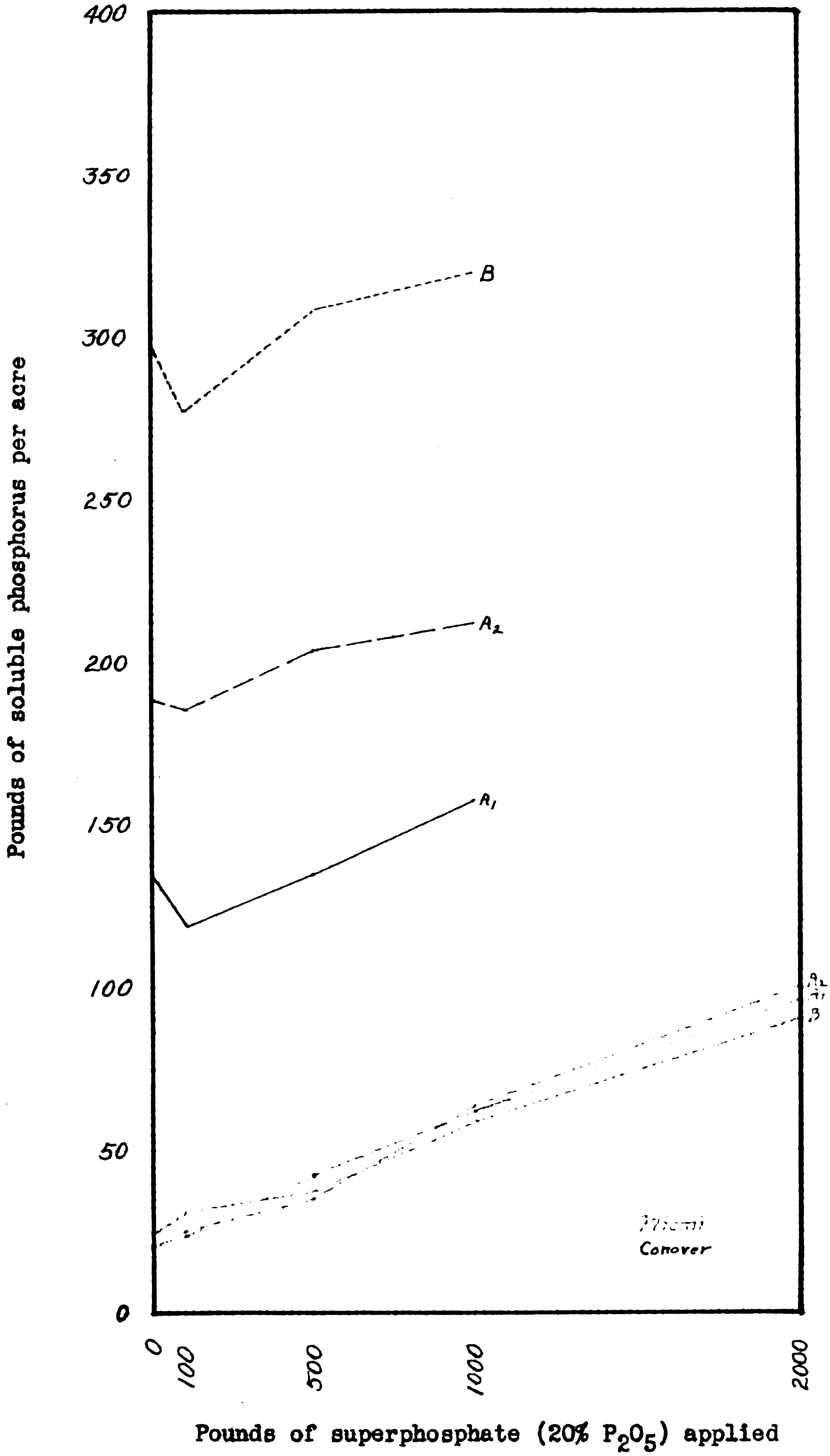
Pounds Per Acre Phosphorus Applied	000	8.73	46.66	87.32	174.64	349.28	Pounds Superphosphate (20% P_2O_5) Applied to Raise Level to 100 Pounds Per Acre Soluble Phosphorus
20% Superphosphate Equivalent	000	100	500	1000	2000	4000	
Soil Type and Horizon	Pounds Per Acre Of Readily Soluble Phosphorus in Soil						
Miami							
A_1	21.07	24.3	43.5	62.1	96.88		2100
A_2	20.2	25.0	35.2	65.8	100.8		2000
B	25.6	31.0	37.4	55.9	90.4		2300
Hillsdale							
A_1	35.6		61.6	84.4	137.2	233.3	1300
A_2	24.0		36.8	63.4	105.7	202.0	1850
B	20.2		42.25	59.3	117.0	206.5	1700
Bellefontaine							
A_1	16.28	19.36	41.9	70.0	126.5		1500
A_2	24.09	32.12	47.85	79.5	116.1		1550
B	50.8	51.2	66.6	87.6	130.5		1275
Conover							
A_1	135.2	119.8	135.6	157.8			
A_2	189.0	186.2	204.1	212.7			
B	297.6	277.2	309.5	320.0			

Figure 1



Pounds of superphosphate (20% P_2O_5) applied

Figure 2



Pounds of soluble phosphorus per acre
400
350
300
250
200
150
100
50
0
B
A2
A1
Conover
0
100
500
1000
2000
Pounds of superphosphate (20% P_2O_5) applied

Table 4. Rate of application of potassium and resultant quantities of readily soluble potassium in soils.

Pounds Per Acre Potassium Applied	000	204.78	409.55	819.10	1638.20	Pounds of Muriate of Potash (50% K_2O) To Raise Level to 100 Pounds Per Acre of Potassium
50% Potassium Chloride Equivalent	000	500	1000	2000	4000	
Soil Type and Horizon	Pounds Per Acre Of Readily Soluble Potassium in Soil					
Miami						
A_1	34.8	80.9	141.1	271.5	513.7	497.6
A_2	18.1	34.3	87.7	207.5	472.6	842.2
B	15.4	29.2	68.2	134.2	271.6	1148.9
Hillsdale						
A_1	42.4	97.0	164.8	311.7	532.1	394.3
A_2	20.7	46.2	76.7	166.1	407.2	976.2
B	15.2	44.1	56.1	123.3	241.8	1263.3
Bellefontaine						
A_1	26.8	87.4	156.5	322.1	709.5	459.4
A_2	12.5	75.3	171.8	363.1	798.6	478.5
B	7.7	18.2	35.4	111.6	288.5	1435.6
Conover						
A_1	8.9	29.7	37.2	78.2	197.7	1799.3
A_2	6.2	12.8	30.4	76.4	210.2	1818.4
B	14.3	16.7	31.6	74.0	200.6	1856.7

Figure 3

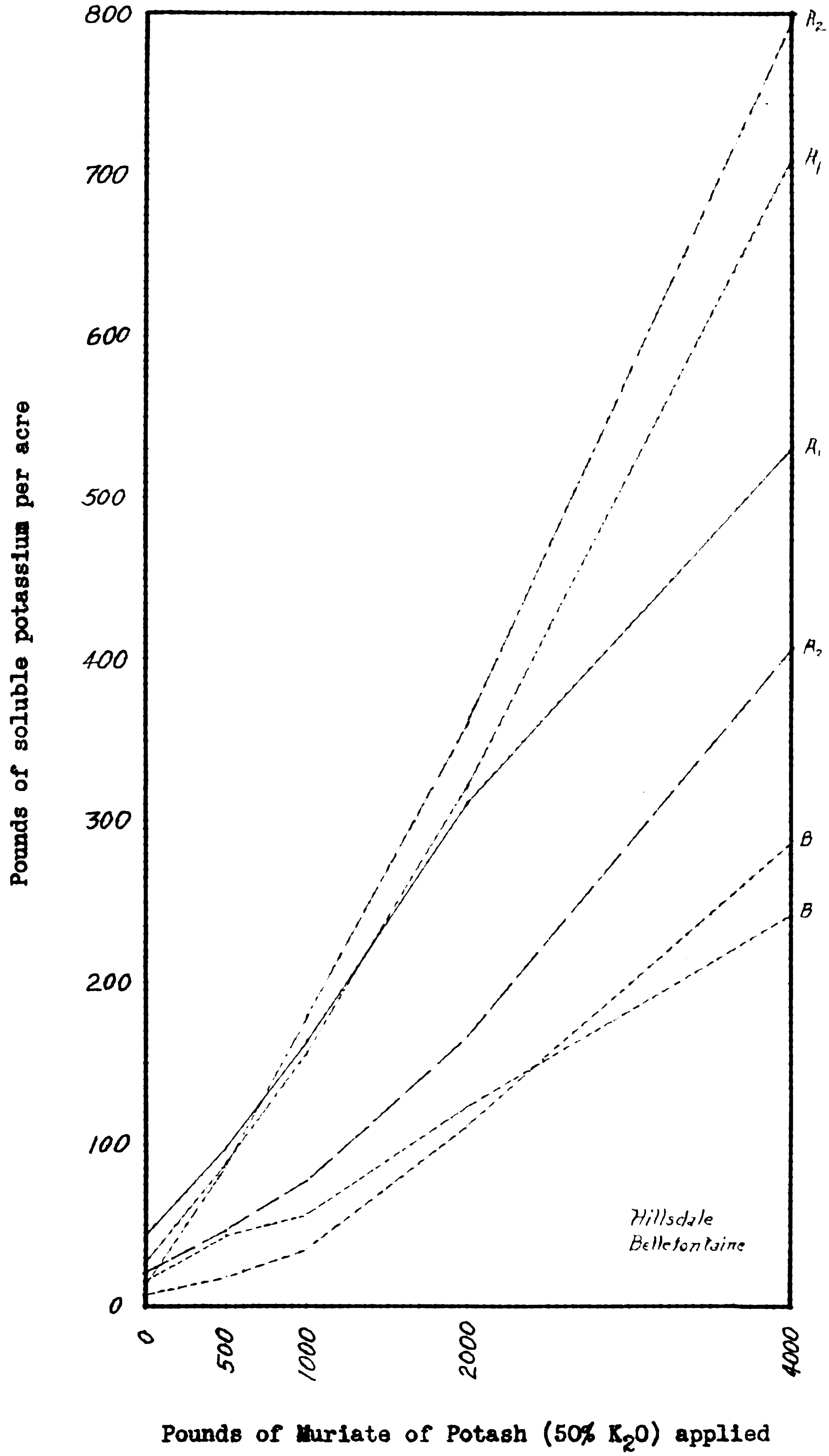
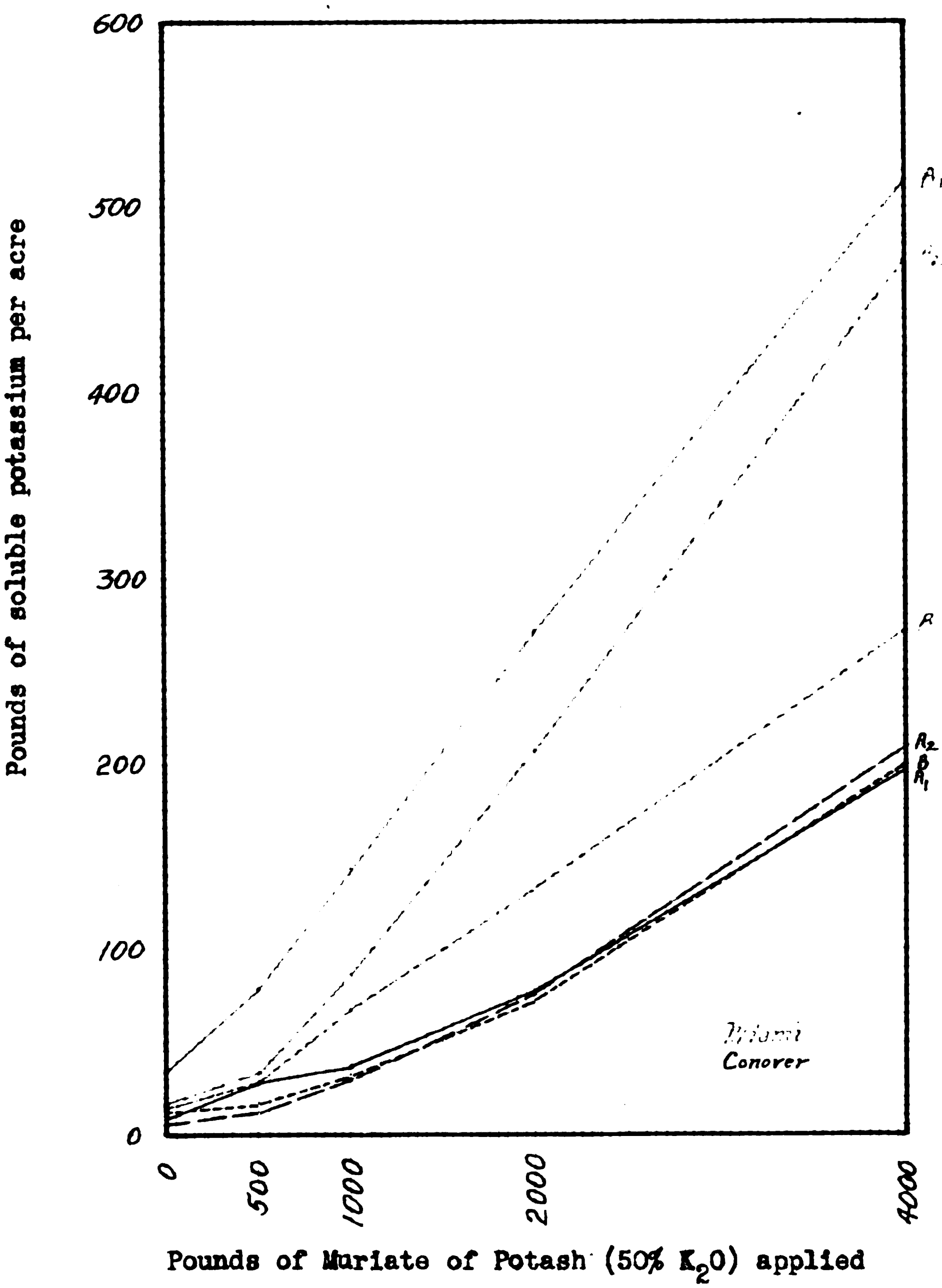

Pounds of soluble potassium per acre
800
700
600
500
400
300
200
100
0
0
500
1000
2000
4000
A2
A1
A1
A2
B
B
Hillsdale
Bellefontaine
Pounds of Muriate of Potash (50% K_2O) applied

Figure 4



600
500
400
300
200
100
0
Pounds of soluble potassium per acre
A_1
A
A_2
B
A_1
Conover
0
500
1000
2000
4000
Pounds of Muriate of Potash (50% K_2O) applied

Greenhouse Experiment

The experiment in the greenhouse was carried out in one-gallon glazed jars, which were brought to equal weight with quartz sand before filling with soil. The fertilizing elements were applied in solution and thoroughly mixed throughout the soil. Potassium and phosphorus were applied at the rates determined in the preceding work, and two hundred pounds per acre of nitrate of soda was applied at the beginning of the experiment and again during the growing period, when the nitrate supply became low. The second crop had only one application of nitrogen, which was made when the crop was about half grown. It was not necessary to add N at the beginning of the second experiment. Potassium and phosphorus were not applied for the second crop, because the desired quantities of these nutrients were present in soluble form.

The moisture content of each soil was then brought to near its moisture equivalent . Throughout the experiment, the jars were maintained at a constant weight with distilled water. The jars were allowed to stand two weeks after applying the fertilizers before planting the first crop.

A definite quantity of the soil was removed from each jar, sudan grass seed was sown, and the soil was replaced, so as to place the seed at the same depth in all jars. In planting the second crop, only sufficient soil was removed to cover the seed to the desired depth. The remainder of the soil was not disturbed in the jars. The jars were moved frequently during the growing period to insure a uniform distribution of sunlight. The crops were harvested when seed had formed. The plants were dried in ovens at 65° C. for twenty-four hours. They were then removed, cooled, and weighed. The yields are recorded in Table 5, each value represents an average of duplicate jars.

DISCUSSION OF RESULTS

The data showing the effect of fertilizers and soil horizons on the yield of sudan grass are given by crops in Table 5. The first crop was planted January 14, and was harvested April 20, 1934. The second crop was planted December 18, 1934, and was harvested March 22, 1935. In general, the first crop was larger than the second. The difference was probably due, in part, to the greater length of day during the growth of the first crop. Other unknown factors undoubtedly affected the yields. The number of days from planting to harvest, however, was practically the same for both crops. The data will be discussed under the heading of the individual soil types.

Miami Silt Loam

The data show that the B horizon of Miami silt loam was more productive, in all cases,for the first crop than was the A_2 horizon. The same results were obtained for the second crop with the no fertilizer, the nitrogen plus potassium, and the complete fertilizer treatments. In the case of the first crop, all fertilizer treatments except nitrogen plus potassium increased the yields of the A_2 and B horizons materially above that of the untreated A_1 horizon. These results were not obtained with any treatment for the second crop. It is noteworthy that the addition of nitrogen plus potassium decreased the yields on both crops for all three horizons, whereas the addition of nitrogen plus phosphorus increased the yields in every case except one.

In general, the A_1, A_2, and B horizons of the Miami silt loam showed similar nutrient deficiencies. The need for phosphorus was greatest, followed by the need for nitrogen. The requirement for potassium was not evident until phosphorus and nitrogen had been supplied. In fact, in every case, the nitrogen plus potassium treatment gave a lower yield than the corresponding untreated soil.

Hillsdale Sandy Loam

The A_1 horizon of Hillsdale produced larger yields of both crops, with all treatments, than the A_2 and B horizons. The productivity of the A_2 and B horizons was not increased to that of the untreated A_1 horizon by any fertilizer treatment used in the experiment. The results for the various fertilizer treatments with the A_2 and B horizons were too inconsistent to permit a definite conclusion to be drawn as to which nutrient element was most deficient, although indications were that phosphorus was most effective in increasing plant growth. In three cases out of four, the nitrogen plus potassium treatment decreased the yield obtained from the untreated A_2 and B horizon soil.

Bellefontaine Sandy Loam

The results for the first crop show that for a maximum plant growth, the soil from each horizon was in need of all three of the nutrients applied. For the first crop, the complete fertilizer treatment of the A_2 and B horizons and the nitrogen plus phosphorus treatment of the B horizon resulted in yields greater than that of the unfertilized A_1 horizon. No treatment of the A_2 or B horizons gave a yield of the second crop equal to that of the unfertilized A_1 horizon. Results from the first crop indicate that phosphorus is the element most needed to increase plant growth on the A_2 and B horizons.

Conover Silt Loam

The Conover soil was found to be naturally high in soluble phosphorus. Notwithstanding the fact that the soluble phosphorus present exceeded the limit set for the experiment,applications of phosphate equivalent to five hundred pounds per acre of 20 percent superphosphate were made where phosphorus treatment is indicated.

Table 5. Yields of sudan grass with and without fertilizer treatments on the A_1, A_2, and B horizons of Miami silt loam, Hillsdale sandy loam, Bellefontaine sandy loam, and Conover silt loam. Grams of dry plant tissue.

	FIRST CROP					SECOND CROP				
Treatment	000	N + K	N + P	P + K	N + P + K	000	N + K	N + P	P + K	N + P + K
Horizon	MIAMI SILT LOAM									
A_1	2.58	1.83	14.29	9.79	15.16	3.12	2.38	4.53	5.82	5.05
A_2	1.84	.22	4.74	4.40	6.85	1.25	.57	2.51	1.64	1.70
B	3.62	.78	5.96	4.78	7.15	1.53	1.06	1.80	1.10	2.23
	HILLSDALE SANDY LOAM									
A_1	9.48	12.68	12.96	14.28	14.61	6.87	8.49	6.64	6.86	7.10
A_2	.16	.23	.25	1.44	2.61	.79	.28	1.12	.66	1.30
B	.24	.19	4.20	.75	3.94	.54	.26	1.72	3.63	2.52
	BELLEFONTAINE SANDY LOAM									
A_1	3.00	2.55	6.63	7.34	9.05	2.16	2.51	3.02	3.13	3.46
A_2	.69	1.19	2.71	2.72	3.75	.75	1.45	1.02	.79	1.02
B	.85	.88	3.23	2.50	3.74	1.64	1.20	.80	.83	1.66
	CONOVER SILT LOAM									
A_1	3.29	6.19	5.31	10.40	10.74	6.15	10.00	7.57	7.82	10.01
A_2	2.35	2.76	3.16	4.24	4.71	2.11	4.53	3.16	2.57	3.58
B	2.59	2.55	3.66	2.70	3.65	1.60	2.06	2.48	1.64	2.31

The data show that all applications of fertilizer to the A_2 horizon increased the yield of sudan grass over that of the untreated soil. With corresponding fertilizer treatments, the A_1 horizon produced greater yields than either the A_2 or B horizons. For the first crop, the phosphorus plus nitrogen and the complete fertilizer treatments gave larger yields on the B horizon than were obtained from the unfertilized A_1 horizon. The same was true for the complete fertilizer and phosphorus plus potassium treatments on the A_2 horizon. Increases in yield from complete fertilizer treatments were relatively greater on the A_1 horizon than on the A_2 and B horizons, especially for the first crop. Notwithstanding the naturally high soluble phosphorus content of this soil, the data for the first crop show that additions of phosphorus increased the yield of sudan grass more than additions of either nitrogen or potassium.

Nutrient Deficiency

The data in Table 6 show the average of the yields for both the first and second crops, using the yield for the untreated surface soil as 100. If we accept the premise that "rawness" of a lower horizon is overcome when a yield equal to that from the untreated surface soil is obtained, it is evident from the data that only those treatments supplying phosphorus on the Miami type and the complete fertilizer treatment on the Bellefontaine type have overcome the "rawness" of the A_2 and B horizon soil.

The columns headed "Percent Decrease Due To The Omission of One Element From N + P + K" are based on the assumption that the maximum yield is obtained from the complete fertilizer treatment, and that the omission of one element from that treatment results in a decrease in yield of plant material, which may be ascribed directly to the deficiency of that element. The data are given as percent decrease in yield.

On the Miami soil type, the percentage decrease is greatest for phosphorus, nitrogen showing the second greatest decrease, and potassium being the least deficient. Exactly the same results are found on the A_2 and B horizons of both the Hillsdale and Bellefontaine types. The Conover type is an exception. The data show the Conover to be most deficient in potassium on the A_1 and A_2 horizons and most deficient in nitrogen on the B horizon.

Table 6. Average yields of two crops of sudan grass, based on the yields of the unfertilized A_1 horizon as 100. Percent decrease in yield due to the omission of one element, based on the results from the complete fertilizer treatment.

		Treatment					Percent Decrease Due To The Omission of One Element From N + P + K Element		
Soil Type	Horizon	000	N + K	N + P	P + K	N + P + K	N	P	K
Miami Silt Loam	A_1 A_2 B	100 54 90	74 16 32	330 127 136	274 106 106	355 150 164	22.8 29.3 35.3	79.1 89.3 80.4	7 15.3 17
Hillsdale Sandy Loam	A_1 A_2 B	100 6 5	130 3 3	120 22 36	136 13 27	133 24 40	-2.3 45.8 32.5	2.3 87.5 92.5	9.7 8.3 10.0
Bellefontaine Sandy Loam	A_1 A_2 B	100 28 48	98 51 41	187 72 78	203 68 65	243 93 105	16.4 26.8 38.0	59.6 45.1 60.9	23.0 22.5 25.7
Conover Silt Loam	A_1 A_2 B	100 57 44	171 77 49	146 67 65	193 72 46	320 88 63	12.2 18.1 26.0	22.3 12.5 22.2	33.6 23.8 -3.2

SUMMARY

A study was made to determine if the unproductiveness of the A_2 and B horizons of four soil types, as indicated by the growth of sudan grass in one-gallon jars of the soil, could be overcome by addition of various combinations of nitrogen, phosphorus, and potassium. Through the addition of fertilizers, the amount of easily soluble phosphorus and potassium in the soils was raised to one hundred pounds to the acre. Since the horizons of the Conover silt loam already contained more than one hundred pounds of easily soluble phosphorus, a uniform application of five hundred pounds per acre of 20 percent superphosphate was made when the fertilizer treatment called for phosphorus. For comparison, the A_1 horizon of each soil type was given the same fertilizer treatments as the A_2 and B horizons received.

The soils were stored for one year after removal from the field. Single crops were grown each of the next two years.

Data for the first crop show that the addition of a complete fertilizer to the A_2 and B horizons of all soil types studied, except the Hillsdale, resulted in a yield in excess of that obtained from the corresponding unfertilized A_1 horizon. The same result was obtained in several instances where other fertilizer combinations were applied. The exceptionally high yields for the Hillsdale A_1 horizon, with or without treatment, place the results for this soil at variance with the results from the other soils studied.

The data for the second crop show that the untreated A_1 horizon gave a greater yield in all cases than that on any treatment of the A_2 and B horizons. This may possibly be due to a greater efficiency of nutrients on cropped soil, as described by Conner (7).

Despite the high content of easily soluble phosphorus contained in the Conover silt loam, the addition of phosphorus carrying fertilizer increased the yield of sudan grass over that obtained from the corresponding unfertilized soil horizon.

From the data, it appears that for all soil types except the Conover, phosphorus is most necessary to maximum plant growth on the subsurface horizons, the need for nitrogen comes next, and potassium is least deficient.

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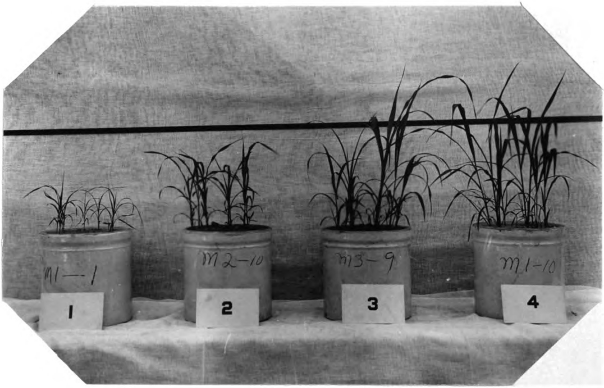
PLATE 1



The effect of complete fertilizer on the A_2 and B horizons of Miami silt loam, as compared to the unfertilized and completely fertilized A_1 horizon. First crop at 60 days after planting.

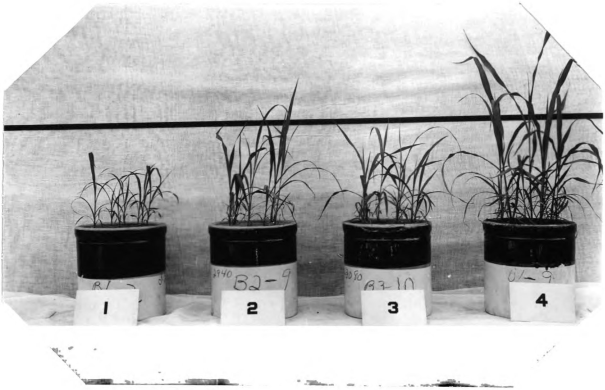
1. A_1 Unfertilized
2. A_2 Complete Fertilizer
3. B Complete Fertilizer
4. A_1 Complete Fertilizer

PLATE 2

The effect of complete fertilizer on the A_2 and B horizons of Hillsdale sandy loam, as compared to the unfertilized and completely fertilized A_1 horizon. First crop at 60 days after planting.

1. A_1 Unfertilized
2. A_2 Complete Fertilizer
3. B Complete Fertilizer
4. A_1 Complete Fertilizer

PLATE 3



The effect of complete fertilizer on the A_2 and B horizons of Bellefontaine sandy loam, as compared to the unfertilized and completely fertilized A_1 horizon. First crop at 60 days after planting.

1. A_1 Unfertilized
2. A_2 Complete Fertilizer
3. B Complete Fertilizer
4. A_1 Complete Fertilizer

PLATE 4

The effect of complete fertilizer on the A_2 and B horizons of Conover silt loam, as compared to the unfertilized and completely fertized A_1 horizon. First crop at 60 days after planting.

1. A_1 Unfertilized
2. A_2 Complete Fertilizer
3. B Complete Fertilizer
4. A_1 Complete Fertilizer