

THE BEHAVIOR OF APPLIED PHOSPHORUS AND POTASSIUM IN ORGANIC
SOIL AS INDICATED BY SOIL TESTS AND THE RELATIONSHIP
BETWEEN SOIL TESTS, GREEN-TISSUE TESTS AND CROP YIELDS

by

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AN ABSTRACT

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College of Agriculture and Applied Science in partial
fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Soil Science

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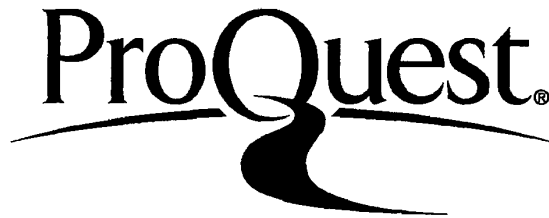
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ABSTRACT

The Behavior of Applied Phosphorus and Potassium in Organic Soil as Indicated by Soil Tests and the Relationship Between Soil Tests, Green-Tissue Tests and Crop Yield

The use of rapid soil tests and tissue tests in arriving at practical fertilizer recommendations and in diagnosing plant nutrient deficiencies has received considerable emphasis. In 1950 an investigation was started to study some of the factors associated with soil and green-tissue analysis with special reference to organic soils.

Soil samples were collected at three consecutive six-inch depths in the spring of 1950 from a series of plots of a fertility experiment started in 1941 and located at the Muck Experimental Farm in Clinton County, Michigan.

Phosphorus was extracted from the soil by four reagents: 0.025N HCl-0.03N NH_4F , 0.1N HCl - 0.03N NH_3F , 0.135N HCl, and 0.018N CH_3COOH . A 1:10 soil:extractant ratio was employed. The mixture was shaken for one minute prior to filtering, and the phosphorus content of the filtrate determined colorimetrically as molybdenum-blue.

Potassium was extracted from the soil by three reagents: 23 percent NaNO_3 , 0.135N HCl, and 0.018N CH_3COOH , using the same extracting procedure as for phosphorus. The extractable potassium was determined with a Perkins-Elmer (model 52A) flame photometer, except for the NaNO_3 extracts in which potassium was determined by a sodium cobaltinitrite procedure.

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The quantity of calcium and magnesium in several NaNO_3 extracts was determined.

Other determinations include: exchangeable hydrogen, cation exchange capacity, percent base saturation, pH, heat of wetting, and hygroscopic moisture.

Water soluble nitrate, phosphorus, and potassium were determined by green-tissue tests of sugar beets, peppermint, and onions at 15-day intervals during the 1951 growing season. A 1:10 green-tissue: water ratio was employed, disintegrating the material for two minutes in a Waring blender prior to filtering. The nitrate and phosphorus content of the filtrate was determined colorimetrically using brucine and molybdenum-blue procedures, respectively. The potassium content was determined by a flame photometer.

A highly significant correlation was found to exist between the amount of phosphorus applied and the amount of phosphorus removed from the soil by any of the four extractants.

The amount of potash applied per acre showed a highly significant correlation with the amount of potassium extracted from the soil by any of the three reagents.

Applied phosphorus was found to remain principally in the surface soil while potassium was found distributed throughout the 18-inch soil profile.

The extractable potassium content was approximately doubled between fall and spring sampling while the content of extractable phosphorus was found to be about the same.

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A mean of 69.3 m.e. of calcium and a mean 12.1 m.e. of magnesium per 100 grams of soil were found in 23 percent NaNO_3 soil extract.

The cation exchange capacity in the surface six inches was found to be 227 m.e. per 100 grams of soil. The exchangeable hydrogen slightly decreased while the percent base saturation and pH slightly increased with soil depth.

No appreciable variation occurred in the properties of heat of wetting and the content of hygroscopic moisture.

Periodic green-tissue tests of sugar beets, peppermint, and onions in the summer of 1951 revealed a seasonal variation in the composition of water extractable nitrate, phosphorus, and potassium in these plants.

Yields correlated better with green-tissue tests than with rapid soil tests.

In correlating rapid soil tests, green-tissue tests, and crop yields, it was impossible to establish optimum levels of phosphorus and potassium for maximum yields of sugar beets and peppermint because of the following factors: the physiological nature of the plants, the seasonal variations in plant composition, the differential response of the crops to the fertilizer ratios, and the limitations in the fertilizer analyses and rates in this experiment.

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INTRODUCTION

Considerable emphasis has been placed on the use of rapid soil tests and tissue tests in arriving at practical fertilizer recommendations and in diagnosing plant nutrient deficiencies (12) (13) (15). Because of the wide distribution of organic soils in Michigan (five million acres) and the increased reclamation of these soils in recent years, an investigation was started in 1950 to study some of the factors associated with soil and green-tissue analysis with special reference to organic soils.

A fertility experiment started in 1941 and located at the Muck Experimental Farm in Clinton County, Michigan was selected on which to carry out this experiment. The principal objectives were as follows: first, to consider the behavior of applied phosphorus and potash in organic soil as indicated by rapid soil tests; second, to compare different methods for extracting phosphorus and potassium from the soil; and third, to study the relationship between soil tests, green-tissue tests and crop yields.

REVIEW OF LITERATURE

In comparison with the amount of work reported on rapid soil tests and tissue tests of crops grown on mineral soils, relatively little work of this nature has been reported for organic soils.

At the Everglades Experiment Station of Florida, Forsee (11) has conducted experiments correlating crop yields with soil and tissue tests on a number of crops. In a fertility experiment with celery on Okeelanta peaty muck, distilled water was found preferable to 0.5N acetic acid as an extractant for phosphorus determination in rapid soil tests. A significant relationship existed between the water soluble phosphorus and the amount of phosphate applied to the soil. The same was true for potassium soluble in 0.5N acetic acid. Green-tissues were extracted with 0.5N acetic acid for phosphorus and potassium determinations. The maximum yield of celery grown on Okeelanta peaty muck was associated with 250 pounds of acid soluble potassium and 30 pounds of water soluble phosphorus per acre, 0.3 and 11.0 percent (dry weight basis) of phosphorus and potassium respectively in the green-tissue, and an adjusted soil pH of 5.5.

With sodium acetate-acetic acid solution buffered to pH 4.8, Dawson (7) found the average potassium content of cultivated peat soils in New York to be 760 ± 650 pounds per acre and the average phosphorus content to be 200 ± 210 pounds per acre. He estimated the safe level of soil-test potassium at not less than 250 nor more than 350 pounds per acre and the level of soil-test phosphorus at not less than

50 pounds per acre. Dawson concluded that when a peat soil was fertilized with potash at a constant rate per acre per year, the available potassium content of the soil as measured by soil-test methods adjusted itself within three to five years to the rate of fertilization and remained constant until the fertilizer practice was changed again. A similar situation occurred for phosphorus providing the content of soil-test iron plus aluminum was less than 100 pounds per acre. When the iron plus aluminum content exceeded 200 pounds per acre, the soil-test phosphorus was found to be 50 pounds or less per acre. The importance of the relationship between the iron plus aluminum content and the available phosphorus composition of cultivated peat soils was emphasized.

Filman and co-workers (9) preferred a mechanical press to extractants in removing extracts from organic soils in Canada. Solutes expressed by pressure from the organic soils appeared to represent the nutrients available to the growing crops where methods used for mineral soils had failed to do so. These investigators reported evidence of mass movements of solutes in both horizontal and vertical directions in the organic soil.

PROCEDURE

The field work of this investigation was conducted in a fertility experiment located at the Muck Experimental Farm in Clinton County, Michigan which was started in 1941. Included in the treatments were ten different fertilizers applied at the rates of 500 and 1,000 pounds per acre referred to as the low and high fertility series. Four of the treatments were replicated five times and the remaining six without replication were intended for demonstration purposes. There were two unfertilized plots. The low fertility series included four 25-foot sections initiated in 1948 which permitted the crops to be rotated, except for brome grass which continuously occupied one section since 1941. Prior to 1948 areas of unequal size were utilized in this experiment. The chief rotated crops were sugar beets, soybeans, wheat, peppermint, and spearmint. The high fertility series was similarly divided into four sections and the following were the main crops rotated in the sections: cabbage, carrots, celery, potatoes, onions, and table beets.

Soil samples were collected at three consecutive six-inch depths in the spring of 1950. Each sample consisted of soil taken at five locations in a 25 x 30 foot plot; the center and nine feet from the center toward the corners. There were 28 plots sampled in each of the low and high fertility series. The samples were screened through a two millimeter sieve when partially dry and allowed to air dry at room temperature.

Soil samples of the surface six inches were taken in the spring and fall of 1950 and 1951 respectively from one plot of each low fertility treatment which was replicated five times.

Phosphorus was extracted from the soil by four reagents: 0.025 N HCl-0.03 N NH_4F and 0.1N HCl-0.03N NH_4F solution proposed by Bray and Kurtz (4), 0.135N HCl and 0.018N CH_3COOH as used by Spurway and Lawton (16). These methods were modified by increasing the soil-extracting solution ratio to 1:10 in order to accommodate the high water absorptive capacity of organic soils and by shaking the mixture of soil-extracting solution for one minute. One-fourth teaspoonful of activated carbon was added to each five grams of soil tested in order to obtain a clear extract. The extractable phosphorus was determined colorimetrically as molybdenum blue employing the ammonium molybdate-hydrochloric acid solution according to Dickman and Bray (8) and the 1-amino, 2-naphthol, 4-sulphonic acid reducing reagent developed by Fiske and Subbarow (10).

When Bray's 0.025N HCl-0.03N NH_4F extracting reagent was used, the clear extract filtered from the soil would become cloudy after standing for a few minutes. The colorimeter readings of these soil extracts were quite irregular and the intensity of the molybdenum-blue color increased exceptionally rapid. The pH of the extract was found to be 4.05 while that of the extracting solution was 2.70. Therefore, it was apparent that the amount of acid supplied in the six drops of the molybdate solution which was added according to the

normal procedure was insufficient to bring about the proper molybdenum-blue color. Possibilities considered for correction were: first, the addition of one drop of concentrated hydrochloric acid; second, the addition of two or more drops of the molybdate solution which contained 3.5N HCl.

Potassium was extracted from the soil by three reagents; 23 percent NaNO_3 as employed by Bray (3), 0.135N HCl, and 0.018N CH_3COOH proposed by Spurway and Lawton (16), making the same modifications in the extracting procedures as for phosphorus. The extractable potassium was determined with a Perkins-Elmer (model 52A) flame photometer using the internal standard method, except for the sodium nitrate extracts in which potassium was determined by a sodium cobaltinitrite procedure.¹

Cheng and Bray (5) have established a technique for the determination of calcium and magnesium in soil and plant material. Since the extraction procedure with 23 percent NaNO_3 solution is quite similar to that for extracting potassium, the quantity of calcium and magnesium in several extracts was determined by this technique to see if these elements were uniformly distributed throughout the experimental area.

¹ Formaldehyde was not used to prevent the interference of possibly occurring ammonia. Subsequent nesslerization tests revealed the presence of less than 10 PPM of ammonia in the soil extract. On this basis potassium values should not vary more than ± 5 percent.

The exchangeable hydrogen and the cation exchange capacity were determined by the method prescribed by Mehlich (14). The exchangeable bases were calculated by difference of the cation exchange capacity and the exchangeable hydrogen. This method was modified by placing one gram samples of dry soil in glass vials each containing five milliliters of distilled water and while the soil was soaking the excess air was removed under partial vacuum for 35 minutes. After standing for 24 hours the samples were transferred to Gooch crucibles fitted with discs of filter paper and the soil was leached under slow vacuum with the prescribed amount of $0.2N \text{ Ba}(\text{CH}_3\text{COO})_2 \cdot \text{H}_2\text{O}$.

In order to check the quantity of exchangeable hydrogen determined by Mehlich's procedure, the exchangeable hydrogen was also determined by the method proposed by Bradfield and Allison (2) which involves bringing a soil sample to equilibrium with $1N \text{ NH}_4\text{Cl}$ - $0.01N \text{ NH}_4\text{OH}$ buffer solution adjusted to pH 7.4 (pH 7.5 in this case) and titrating the excess base with a $0.01N \text{ HCl}$ solution using methyl red as an indicator. The method in this case involved agitating a one gram sample of air dry soil with 100 milliliters of buffer solution in a 250 milliliter flask in an end-over-end manner for two hours. The flasks remained closed for 48 hours after which the contents were filtered and 50-milliliter aliquots titrated potentiometrically to an end point of pH 5.1.

The pH of all samples from the plots receiving the high fertility treatment was determined with a Beckman AC (model H-2) pH meter,

using a 1:5 soil:water ratio. The soil and water were mixed thoroughly and allowed to stand for 15 minutes before inserting the electrodes and making the determination.

Heat of wetting was proposed a little over a quarter of a century ago as a means of estimating the colloidal material in soils (1). This technique was used in this investigation to determine if the depth of the soil from which soil samples were taken or fertilizer treatment had an influence on heat of wetting of organic soils.

The percent hygroscopic moisture was determined for samples from four representative plots at the three depths, 0 to 6, 6 to 12 and 12 to 18-inch.

Preliminary green-tissue tests were made during the 1950 growing season to establish a suitable technique for determining the concentration of water extractable nitrate, phosphorus and potassium. Recently developed tissue was selected, keeping in mind the preference of using stems and petioles instead of leaves in order to eliminate the interference of chlorophyll (6). Potato petioles, onion leaves and mint stems were selected at random from plants on the plots. The green-tissue was placed immediately in cellophane bags and kept frozen until analyzed.

Each sample was sliced into thin sections while frozen, thoroughly mixed, and 10 grams of the frozen tissue placed in a Waring blender with 100 milliliters of distilled water. After the blender disintegrated the material for two minutes, the dispersed tissue was

filtered in a Büchner funnel under suction. In the case of onions the mucous substance found in the leaves necessitated the use of two teaspoonfuls of celite 503, a flocculating agent, to expedite filtering. Thirty-five milliliters of the initial filtrate was clarified by adding one-fourth teaspoonful of activated carbon and refiltering.

Water soluble nitrate, phosphorus and potassium were determined colorimetrically on the final filtrate using brucine, molybdenum-blue, and sodium cobaltinitrite methods, respectively.

Green-tissue tests were made at 15-day intervals during the 1951 growing season to determine the seasonal changes in the concentration of water extractable nitrate, phosphorus and potassium in onion, sugar beet and peppermint plants. Each sample was collected from five random locations in the plot. The samples were wrapped in cellophane bags in the field and placed in an insulated cardboard box containing "dry ice" to inhibit chemical changes. The samples were later placed in a cold room at 0° Centigrade and allowed to remain at that temperature until analyzed.

The extracts were obtained and analyzed in the same manner as the 1950 determinations, except that the flame photometer was used in determining the extractable potassium.

RESULTS AND DISCUSSION

The amount of phosphorus extracted from the soil by all of the four reagents was closely correlated with the amount of phosphorus applied, as shown in Figure 1. The correlation coefficients for these reagents were 0.986, 0.915, 0.943 and 0.967 for 0.1N HCl - 0.03N NH_4F , 0.135N HCl, 0.025N HCl - 0.03N NH_4F , and 0.018N CH_3COOH , respectively.

When analyzing the soil extract received by using the 0.025N HCl - 0.03N NH_4F solution, one drop of concentrated hydrochloric acid was added to the extract before the addition of the molybdate and the reducing reagents. A blue color of less intensity and more stability was formed which faded only one percent transmission in 15 minutes, as shown in Table I. One drop of concentrated hydrochloric acid did not cause excessive acidity in the extract being tested because its normality was less than those receiving eight and ten drops of the molybdate reagent as shown in Table II. The addition of one drop of concentrated hydrochloric acid to the 10 milliliters of extract was preferable to two or four extra drops of molybdate solution because the ratio of molybdate:reducing solutions was unchanged and the blue color was more stable. A possible reason for the cloudiness of the clear extract was the formation of a calcium fluoride precipitate. This soil was found to contain 69 m.e. of exchangeable calcium and 12 m.e. of exchangeable magnesium per 100 grams of soil.

A comparison of the potassium extracting reagents on the amount of potassium removed from the soil, as illustrated in Figure 2, shows

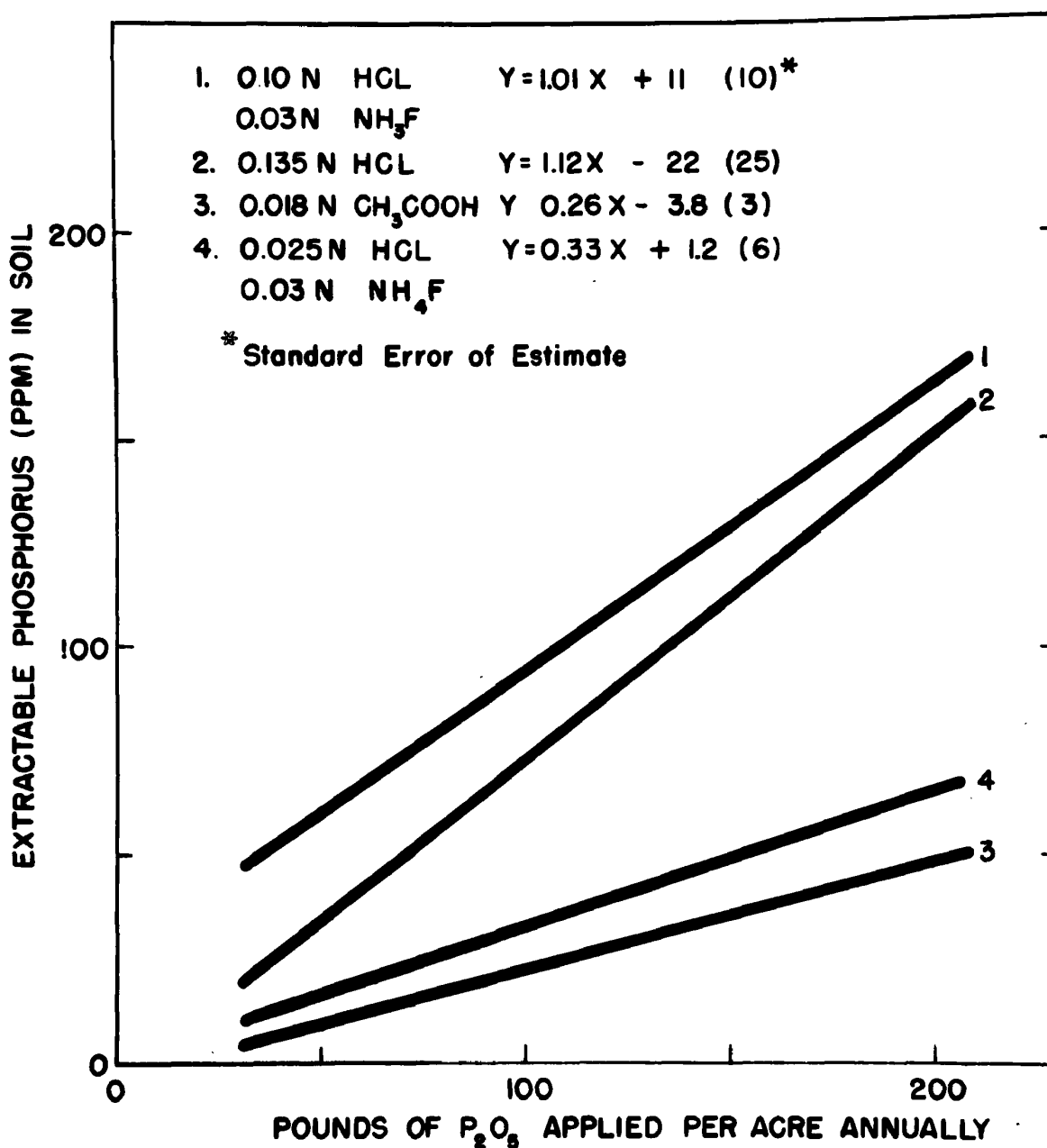


Figure 1. A comparison of the amounts of extractable phosphorus recovered by four methods from the 6-inch depth of organic soil treated with different amounts of phosphorus for a nine-year period.

TABLE I

THE EFFECT OF THE NUMBER OF DROPS OF MOLYBDATE - HYDROCHLORIC ACID
AND REDUCING (F-S) REAGENTS ON THE FORMATION OF THE MOLYBDENUM-BLUE
COLOR IN STANDARD AND SOIL EXTRACT SOLUTIONS

Number of drops of reagents	Time in minutes between mixing and reading	Percent transmission		PPM phosphorus	
		Standard	Extract	Standard	Extract
6 molybdate	15	44	67	2.21	1.08
6 F-S	30	43	61	2.29	1.35
6 molybdate	15	44	76	2.21	0.74
6 F-S	30	44	75	2.21	0.77
1 conc. HCl					
8 molybdate	15	45	70	2.18	0.95
6 F-S	30	44	64	2.21	1.20
10 molybdate	15	44	72	2.21	0.87
6 F-S	30	43	69	2.29	1.00
10 molybdate	15	44	70	2.21	0.95
8 F-S	30	43	64	2.29	1.19
10 molybdate	15	44	71	2.21	0.96
10 F-S	30	42	67	2.35	1.14

TABLE II

THE INFLUENCE OF ONE DROP OF CONCENTRATED HYDROCHLORIC ACID AND TWO OR MORE DROPS OF MOLYBDATE ON THE NORMALITY OF THE SOLUTION AND STABILITY OF THE MOLYBDENUM-BLUE COLOR

Number of drops of reagents	Normality of solution	Percent transmission		PPM P		Differ- ence
		15 min.	30 min.	15 min.	30 min.	
6 molybdate 6 F-S	0.241	77	64	0.70	1.20	0.50
6 molybdate 6 F-S 1 conc. HCl	0.262	87	82	0.38	0.54	0.16
8 molybdate 6 F-S	0.307	80	69	0.60	1.00	0.40
10 molybdate 6 F-S	0.376	86	80	0.40	0.60	0.20

considerable variation between the amounts of potassium applied and the amount extracted. Nevertheless, the correlation coefficients for these reagents are highly significant with corresponding values of 0.640, 0.667 and 0.671 for 23 percent NaNO_3 , 0.135N HCl, and 0.018 N CH_3COOH , respectively.

The data in Table III show that phosphorus applied to the soil remained largely in the surface six inches. However, there are definite indications of the movement of phosphorus down as far as the 12 to 18-inch depth in the profile, as shown in Table IV. The downward movement of phosphorus is manifested by a significant difference in most cases of the extractable phosphorus found in the 12 to 18-inch depth of plots receiving both rates of 0-20-10 fertilizer in contrast to that found in

the same depth of plots receiving both rates of 0-10-10, 0-10-20, and 0-10-30 fertilizers.

Applied potassium was leached from the surface layer and moved down to the lower depths, as shown by the data in Table V. These data also show that as the potassium in the fertilizer analysis was increased there was a highly significant increase in the amount of potassium extracted from the three consecutive six-inch layers of the soil. However, when the rate of fertilizer application was increased from 500 to 1,000 pounds per acre, the amount of extractable potassium in the soil failed to increase accordingly, and was found to be about the same. The reason for the latter condition is probably due more to the effect of leaching than to crop removal because the demonstration plots which received the 0-0-30 lost very little potassium by crop removal, since the yields were generally low for most crops, yet the potassium extracted from the soil of the plots receiving different rates of potash was practically equal in concentration.

Although the data in Table VI were obtained from single plots, there was a definite trend for the concentration of extractable soil phosphorus to be higher in the fall and the concentration of extractable soil potassium to be considerably higher in the spring. Since the samples were taken in the spring before the application of fertilizer, residual phosphorus may be the explanation for the increase in fall samples. The increase in extractable potassium between fall and spring must be due to the liberation of non-extractable potassium during the winter, probably due to the effect of freezing and thawing.

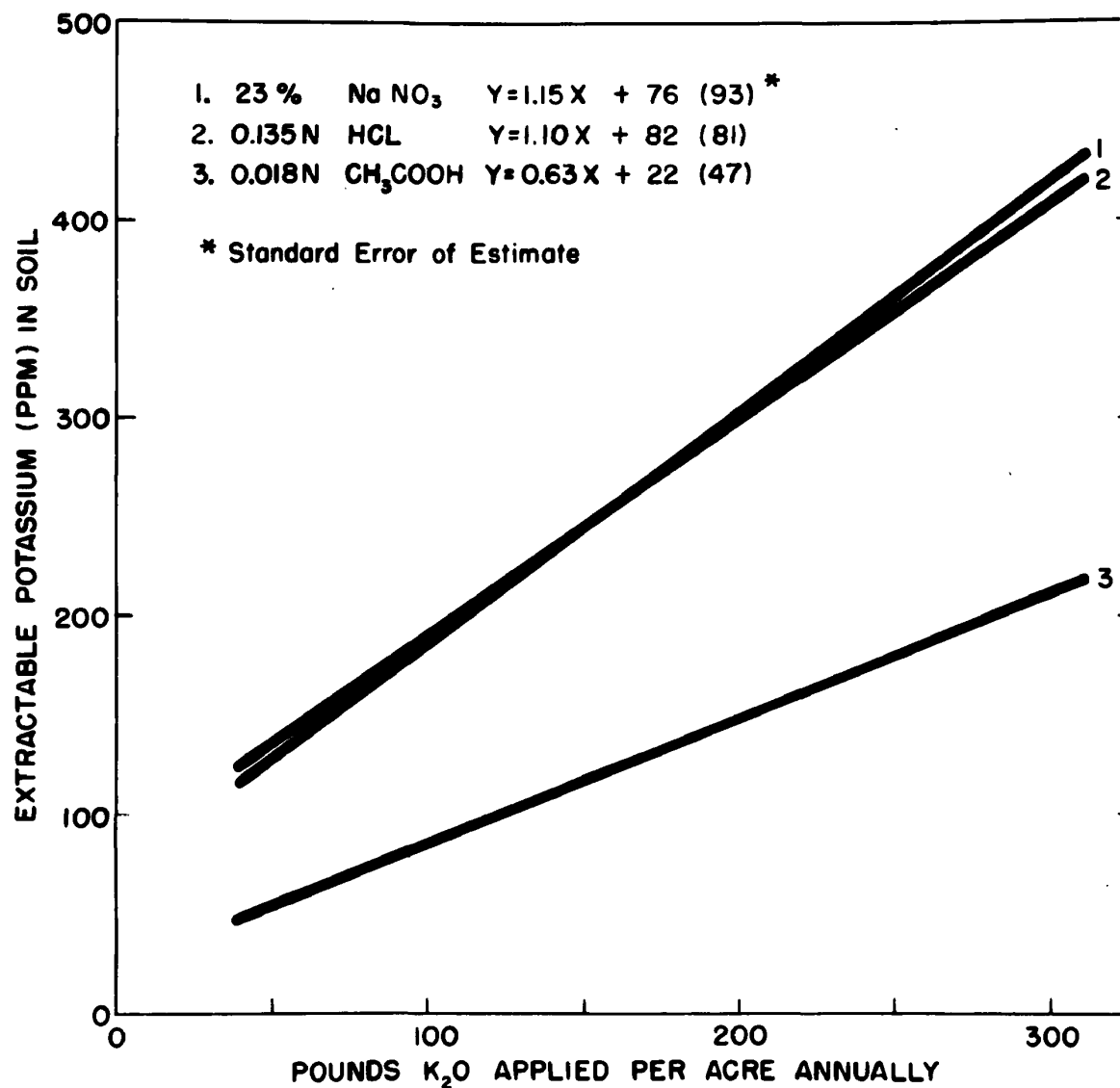


Figure 2. A comparison of the amounts of extractable potassium recovered by three methods from the 6-inch depth of organic soil treated with different amounts of potash for a nine-year period.

TABLE III

THE INFLUENCE OF EXTRACTING REAGENT, FERTILIZER TREATMENT, AND DEPTH OF SAMPLING ON THE AMOUNT OF EXTRACTABLE PHOSPHORUS IN ORGANIC SOIL

Treatment*	Extracting reagent														
	0.018N CH ₃ COOH					0.135N HCl					0.1N HCl				
	0.025N HCl					0.03N NH ₄ F					0.03N NH ₄ F				
	Sampling depth in inches														
Fertilizer	Pounds per acre			Pounds P ₂ O ₅ per acre											
	0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18
None	0	5	3	2	17	13	11	52	18	10	13	8	3		
	0	6	3	1	14	13	7	49	15	7	17	6	2		
0-10-10	500	13	5	3	42	18	9	78	31	9	21	9	3		
	1000	25	6	2	116	17	9	128	17	11	42	7	3		
0-20-10	500	26	7	2	88	22	9	132	34	11	37	10	3		
	1000	54	7	3	231	30	17	253	30	15	68	9	6		
0-20-0	500	38	10	2	119	33	10	159	39	9	48	15	3		
	1000	80	7	1	275	69	13	378	64	14	100	17	5		

* All data averages of five replications except 0-20-0 and unfertilized plots which are 1 and 2 replications, respectively.

TABLE IV

A COMPARISON OF THE AMOUNT OF EXTRACTABLE PHOSPHORUS AND THE INFLUENCE OF THE EXTRACTANT ON THE AMOUNT OF PHOSPHORUS RECOVERED FROM 0 TO 6, 6 TO 12 AND 12 TO 18-INCH DEPTHS OF ORGANIC SOIL TREATED AT DIFFERENT RATES OF PHOSPHORUS APPLICATION FOR A NINE-YEAR PERIOD

Extractant	Depth in inches	Pounds P ₂ O ₅ applied per acre annually			
		Low fertility series ¹		High fertility series	
		50	100	100	200
Pounds P ₂ O ₅ per acre extracted					
0.018N CH ₃ COOH	0-6	12.27	25.97**	26.31	53.68**
	6-12	5.32	6.71	6.09	7.35
	12-18	2.87	2.68	2.94	3.59
0.135N HCl	0-6	42.74	87.71**	106.40	231.75**
	6-12	18.93	22.21	20.84	29.54*
	12-18	9.62	8.70	9.39	16.72**
0.025N HCl 0.03N NH ₄ F	0-6	21.22	37.10**	41.99	68.01**
	6-12	9.79	10.51	7.71	9.34
	12-18	3.27	3.71*	2.76	5.31**
0.1N HCl 0.03N NH ₄ F	0-6	75.72	132.13**	127.18	253.50**
	6-12	29.39	34.57	21.98	29.54
	12-18	10.08	10.99*	10.39	14.66*

¹ Low fertility = 500 pounds fertilizer annually.
High fertility = 1,000 pounds fertilizer annually.

* Significant at 5% level.

** Significant at 1% level.

TABLE V

THE INFLUENCE OF EXTRACTING REAGENT, FERTILIZER TREATMENT,
AND DEPTH OF SAMPLING ON THE AMOUNTS OF EXTRACTABLE POTASSIUM
IN ORGANIC SOIL

Treatment*		Extracting reagent								
		0.018N CH ₃ COOH			0.135N HCl			23% NaNO ₃		
Fertilizer	Pounds per acre	Sampling depth in inches								
		0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18
Pounds of K ₂ O per acre										
None	0	17	5	Trace	43	34	26	20	20	Trace
	0	6	8	8	41	40	25	18	12	5
0-10-10	500	35	7	7	82	42	28	67	21	Trace
	1000	28	11	7	74	34	25	74	8	4
0-10-20	500	73	22	16	155	90	37	167	95	10
	1000	52	20	13	121	55	43	125	23	15
0-10-30	500	108	39	24	213	130	54	223	122	29
	1000	126	37	27	244	124	53	239	95	45
0-0-30	500	204	66	53	219	146	61	336	210	81
	1000	204	80	71	239	136	104	324	246	108

* All data averages of five replications except for 0-0-30 and no fertilizer plots which are 1 and 2 replications, respectively.

TABLE VI

A COMPARISON OF THE PHOSPHORUS AND POTASSIUM EXTRACTED BY 0.135N HCl
FROM SAMPLES OF 6-INCH DEPTH OF ORGANIC SOIL COLLECTED IN THE
SPRING AND FALL

Fertilizer*	Sampling data							
	Spring 1950	Fall 1950	Spring 1951	Fall 1951	Spring 1950	Fall 1950	Spring 1951	Fall 1951
500 pounds per acre	Pounds P ₂ O ₅ per acre				Pounds K ₂ O per acre			
None	17	17	18	18	44	36	40	40
0-20-10	82	101	110	124	75	32	60	48
0-10-10	42	55	57	54	72	40	148	40
0-10-20	53	61	49	57	204	72	252	132
0-10-30	46	55	49	54	242	156	360	164
Mean	48	58	57	61	127	67	172	85

* Data from one plot of each fertilizer treatment

The calcium and magnesium content of the soil as extracted was found to be distributed relatively uniform throughout the plots of the experimental area as shown by the data in Table VII. The quantity of exchangeable calcium decreases slightly with an increase in depth, whereas no definite pattern appears to exist in the case of magnesium.

The data in Table VIII show the amount of exchangeable hydrogen determined by two methods which agree very well with one another. A slight decrease in the milliequivalents of exchangeable hydrogen (Mehlich's procedure) and a very slight increase in percent base saturation is noted with an increase in the depth of the soil. The mean

TABLE VII

THE AMOUNT OF CALCIUM AND MAGNESIUM EXTRACTED FROM ORGANIC SOIL AT
0 TO 6, 6 TO 12 AND 12 TO 18-INCH DEPTHS DETERMINED BY METHOD
OF CHENG AND BRAY (5)

Treatment		Sampling depth in inches					
Fertilizer 1000 pounds per acre	Plot number	0-6	6-12	12-18	0-6	6-12	12-18
		M.e. extractable Ca			M.e. extractable Mg		
None	20	83.9	58.6	56.4	13.8	13.0	17.4
	31	83.4	55.8	65.2	13.4	11.5	13.4
	Mean	83.6	57.2	60.8	13.6	12.2	15.4
0-10-20	3	69.6	65.2	45.9	11.5	14.6	8.7
	7	67.4	60.8	56.9	12.2	14.6	9.7
	13	71.8	68.5	45.3	13.0	15.0	9.5
	17	68.5	64.1	53.0	11.5	14.6	11.1
	27	69.0	65.2	55.8	11.8	14.6	9.3
	Mean	69.5	64.8	51.3	12.0	14.7	9.3
0-10-30	4	69.6	69.6	48.1	12.6	12.6	10.7
	8	67.9	61.9	49.7	13.4	11.1	13.0
	14	69.6	60.8	44.2	12.6	13.4	11.1
	18	69.0	66.3	49.2	11.8	13.8	11.7
	26	69.6	50.3	43.1	11.1	12.6	9.1
	Mean	69.1	61.8	46.9	12.3	12.7	11.1
Mean of fert- ilized plots		69.3	63.3	49.1	12.1	13.7	10.2

TABLE VIII

THE EXCHANGEABLE HYDROGEN, THE CATION EXCHANGE CAPACITY, THE EXCHANGEABLE BASES, AND THE PERCENT BASE SATURATION OF THE 0 TO 6, 6 TO 12, AND 12 TO 18-INCH DEPTHS OF ORGANIC SOIL

Plot number	Sample number	M.e. per 100 grams air dry soil				
		Exchangeable hydrogen		Cation exchange capacity	Exchangeable bases	Percent base saturation
		Bradfield-	Mehlich			
		Allison				
0 to 6-Inch depth						
1	1	18.2	20.3	234.0	213.7	91.3
	2	21.2	20.1	221.0	200.9	90.9
16	1		21.4	236.8	215.4	91.0
	2		21.0	224.0	203.0	90.6
31	1		21.8	226.8	205.0	90.4
	2		20.7	218.0	197.3	90.5
	Mean	19.7	20.9	226.6	205.9	90.8
6 to 12-inch depth						
1	1	18.4	19.9	208.8	188.9	90.5
	2	18.8	19.5	203.2	183.7	90.4
16	1		19.0	204.0	185.0	90.7
	2		16.2	227.2	211.0	92.9
31	1		20.6	212.8	192.2	90.3
	2		19.3	212.0	192.7	90.9
	Mean	18.6	19.1	211.3	192.2	90.9
12 to 18-inch depth						
1	1	20.8	17.7	194.4	176.7	90.9
	2	19.2	18.5	206.4	187.9	91.1
16	1		15.8	216.0	200.2	92.7
	2		16.2	212.8	196.6	92.4
31	1		18.7	211.2	192.5	91.1
	2		17.9	228.0	210.1	92.1
	Mean	20.0	17.4	211.4	194.0	91.7

cation exchange capacity of the surface six inches of the soil was found to be 227 m.e. per 100 grams of soil. Values for the 6 to 12 and the 12 to 18-inch depths were relatively the same; namely, 211 m.e. per 100 grams of soil.

Data from Tables V and VII indicate that the 23 percent NaNO_3 rapid soil test method removed from the soil a maximum of 28.7 m.e. of potassium (336 pounds of K_2O per acre), a mean of 69.3 m.e. of calcium and a mean of 12.1 m.e. of magnesium or a total of 110.1 m.e. per 100 grams of soil which represents less than 50 percent base saturation. The reason for such a discrepancy was probably caused by the short time of contact (one minute) between the soil and the extractant in the case of the rapid soil test while the time of contact between the soil and extractant was 24 hours in the case of Mehlich's procedure. In the latter procedure the soil was leached with 50 milliliters of $\text{Ba}(\text{CH}_3\text{COO})_2 \cdot \text{H}_2\text{O}$ which was added in increments of five milliliters.

The pH of the soil was quite uniform throughout the experimental area and the pH increased as depth of soil sampling increased as shown in Table IX.

Depth apparently has more influence on the heat of wetting property of the soil than treatment, but neither has much effect, as reported in Table X.

Depth had no appreciable influence on the content of hygroscopic moisture of the air dry samples as shown in Table XI.

TABLE IX

THE pH OF ORGANIC SOIL AT 0 TO 6, 6 TO 12, AND
12 TO 18-INCH DEPTHS FROM PLOTS RECEIVING 1000
POUNDS OF FERTILIZER PER ACRE ANNUALLY

Treatment	Plot number	Depth in inches		
		0-6	6-12	12-18
		pH values		
0-20-10	1	6.3	6.3	6.4
	5	6.4	6.5	6.7
	11	5.9	6.2	6.3
	15	6.3	6.4	6.5
	29	6.3	6.3	6.4
0-10-10	2	6.3	6.4	6.5
	6	6.2	6.4	6.6
	12	6.2	6.3	6.4
	16	6.2	6.5	6.5
	28	6.3	6.3	6.3
0-10-20	3	6.3	6.5	6.8
	7	6.2	6.3	6.4
	13	6.1	6.3	6.5
	17	6.2	6.4	6.5
	27	6.3	6.3	6.5
0-10-30	4	6.4	6.4	6.6
	8	6.2	6.3	6.3
	14	6.2	6.3	6.5
	18	6.2	6.3	6.4
	26	6.2	6.3	6.4
None	20	6.1	6.2	6.4
	31	6.2	6.2	6.4
0-0-30	21	6.2	6.3	6.3
0-5-30	22	6.2	6.3	6.3
0-10-30	23	6.1	6.3	6.4
0-15-30	24	6.3	6.3	6.4
0-10-40	25	6.4	6.3	6.3
0-20-0	30	6.1	6.2	6.4

TABLE X

THE INFLUENCE OF DEPTH AND FERTILIZERS ON THE
HEAT OF WETTING DETERMINATIONS IN ORGANIC SOIL

Plot	Pounds per acre	Sample number	Depth in inches		
			0-6	6-12	12-18
			Calories per gram of soil		
26	100 P ₂ O ₅	1	32.85	27.04	28.26
	300 K ₂ O	2	33.26	26.37	29.98
26	50 P ₂ O ₅	1	31.36	28.27	29.67
	150 K ₂ O	2	33.06	29.41	26.09
5	100 P ₂ O ₅	1	31.47	29.42	29.92
	50 K ₂ O				
20	None	1	33.06	26.52	30.55
Mean			32.51	27.84	29.08

TABLE XI

THE HYGROSCOPIC MOISTURE CONTENT OF AIR DRY SOIL AT
0 TO 6, 6 TO 12, AND 12 TO 18-INCH DEPTHS FROM
SEVERAL OF THE EXPERIMENTAL PLOTS

Plot number	Pounds per acre	Sample number	Depth in inches		
			0-6	6-12	12-18
			Percent hygrosopic moisture		
5	100 P ₂ O ₅ 50 K ₂ O	1	12.72	12.92	12.66
		2	12.41	12.42	12.30
		3	11.87	12.09	11.57
		Mean	12.33	12.48	12.18
26	50 P ₂ O ₅ 50 K ₂ O	1	12.69	12.44	11.41
		2	12.37	12.50	12.32
		3	--	12.78	11.77
		Mean	12.53	12.24	11.83
26	100 P ₂ O ₅ 100 K ₂ O	1	12.51	12.74	13.33
		2	12.51	12.54	12.83
		3	11.89	12.03	12.71
		Mean	12.97	12.44	12.96
20	None	1	12.76	12.55	13.78
		2	12.63	12.22	13.11
		3	12.01	11.81	12.22
		Mean	12.47	12.19	13.04
Mean of all trials			12.40	12.42	12.50

Green-tissue tests in 1950 showed an increase in the water extractable phosphorus and potassium when these elements were applied to the soil as shown by the data in Table XII. The greatest concentration of phosphorus occurred in the green-tissue when phosphorus was applied alone as a fertilizer, while the smallest concentration occurred when potash was applied alone. When the amount of applied phosphorus was doubled, the concentration of the water extractable phosphorus was almost doubled in potatoes and peppermint, but little difference was noted in onions. When the applied potash was increased, there was a consistent increase in concentration of the water extractable potassium in the tissue of potatoes, onions and peppermint, except for a decrease when the amount of potash was increased from 200 pounds to 300 pounds per acre applied for potatoes.

The 1951 green-tissue tests with sugar beet petioles showed an increase in the concentration of water extractable phosphorus when the amount of phosphorus applied was increased from 50 to 100 pounds of phosphate fertilizer per acre per year as illustrated in Figure 3. The tissue collected on three of the seven sampling dates showed significant increases in extractable phosphorus when the amount of phosphorus extracted and applied were compared. Foliar symptoms of potassium deficiency appeared after the second sampling date and this condition probably had some bearing on the phosphorus results obtained.

The water extractable potassium in green sugar beet tissue as influenced by the different amounts of potassium applied to the soil was

TABLE XII

THE INFLUENCE OF FERTILIZER TREATMENT ON THE AMOUNT OF WATER
EXTRACTABLE PHOSPHORUS AND POTASSIUM IN THE GREEN-TISSUE
OF POTATOES, ONIONS, AND PEPPERMINT GROWN IN 1950

Treatment*	Number of plots	Green tissue of crop					
		Potato	Onion	Pepper-	Potato	Onion	Pepper-
		petioles	leaves	mint stems	petioles	leaves	mint stems
PPM of phosphorus				PPM of potassium			
0-0-0	2	10	123	114	65	85	88
0-20-10	5	186	214	251	4174	1316	1638
0-10-10	5	116	183	163	4420	1483	1878
0-10-20	5	108	203	129	5744	1796	3646
0-10-30	5	110	182	126	5290	2056	5652
0-10-40	1	---	185	98	----	1600	6000 [†]
0-20-0	1	---	275	365	----	125	75
0-0-30	1	---	80	35	----	2750	6000 [†]
0-5-30	1	---	175	58	----	1980	5750
0-15-30	1	---	185	170	----	1980	5000

* Data of replicated plots averaged. One thousand pounds of fertilizer per acre for potatoes and onions; 500 pounds per acre for peppermint.

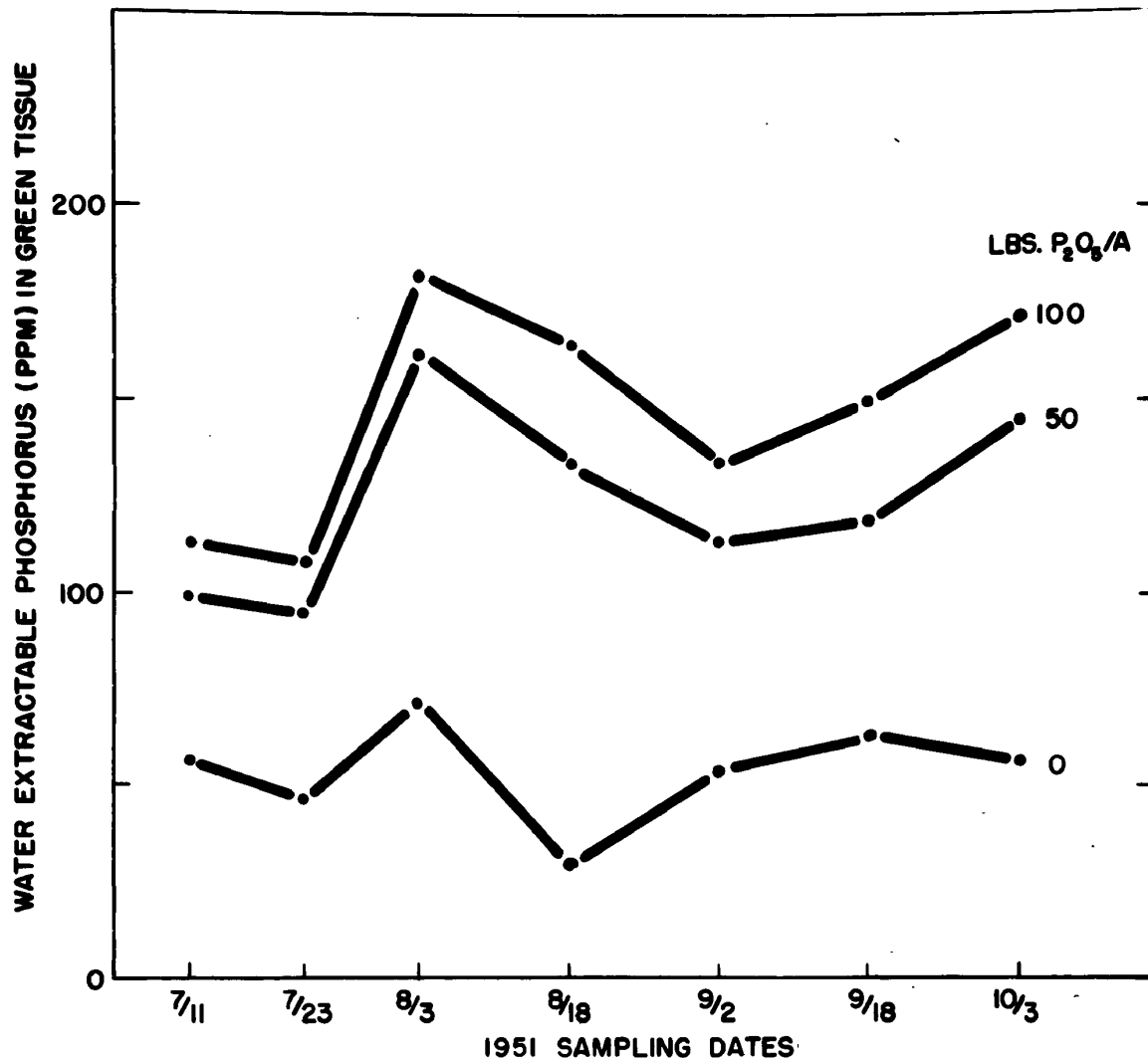


Figure 3. Seasonal changes in the concentration of water extractable phosphorus in sugar beet petioles as influenced by different amounts of phosphorus applied annually to an organic soil for a 10-year period.

highly significant throughout the growing season and foliar symptoms of potassium deficiency were observed after the second green-tissue sampling date (July 23) where 50 pounds and less of potassium was applied per acre per year as shown in Figure 4.

The extractable nitrate in the tissue of sugar beets fertilized with phosphorus and potash decreased in concentration until late in the season as reported in Table XIII. Only two sampling dates showed the concentration of extractable nitrate in the green tissue to be significantly different. The greatest amount of water soluble nitrate was found in the tissue of the unfertilized sugar beets.

In peppermint plants the green-tissue test data of 1951 show that the concentration of water soluble phosphorus was influenced significantly by different amounts of phosphorus applied as illustrated in Figure 5. This influence was highly significant in most cases.

According to the data in Figure 6 the water soluble potassium content in the same peppermint plants was significantly increased when the application of potash was 50 or 100 pounds per acre per year. With the rate of 150 pounds of potash per acre no significant increase in water soluble potassium was noted at any sampling date over the 100 pound application.

The extractable nitrate decreased for each sampling date of peppermint green-tissue, as shown in Table XIV. The applied phosphorus and potash apparently had little influence on the concentration of extractable nitrate in the green tissue.

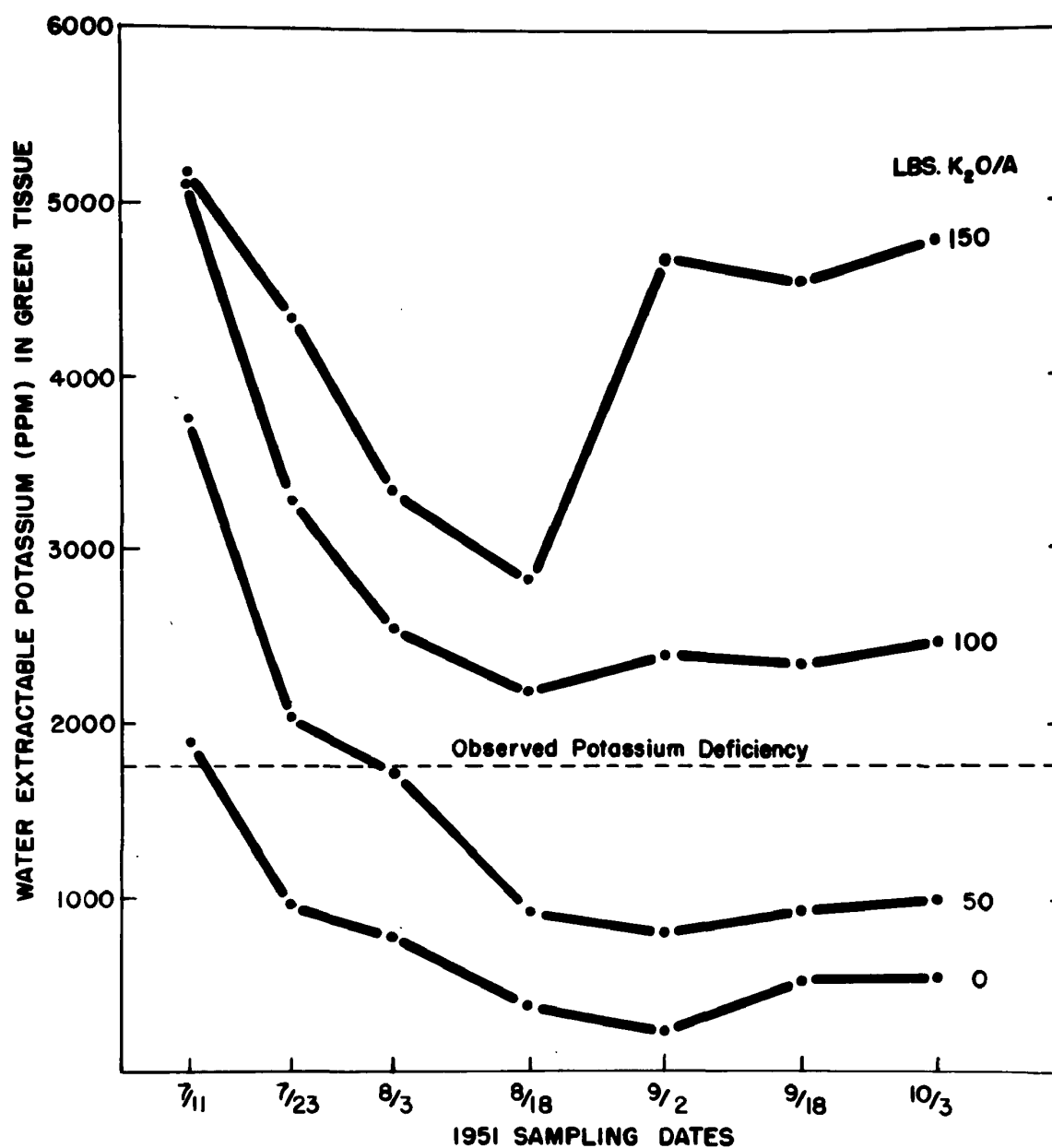


Figure 4. Seasonal changes in the concentration of water extractable potassium in sugar beet petioles as influenced by different amounts of potash applied annually to an organic soil for a 10-year period.

TABLE XIII

SEASONAL CHANGES IN THE CONCENTRATION OF WATER EXTRACTABLE NITRATE
IN SUGAR BEETS AS INFLUENCED BY DIFFERENT AMOUNTS OF PHOSPHORUS
AND POTASH APPLIED ANNUALLY TO AN ORGANIC SOIL FOR A 10-YEAR PERIOD

Treatment ¹		Sampling date of 1951							Mean (season)
Fertilizer	Pounds per acre	7-11	7-23	8-3	8-18	9-2	9-18	10-13	
PPM of extractable nitrate									
0-0-0	None	1880	980	1080	1140	1140	900	860	1180
0-20-10	500	1152	856	920	464	252	215	212	582
0-10-10	500	1152	1000	800	380	236	212	224	572
0-10-20	500	1024	892	624	192	260	128	212	476
0-10-30	500	1560	728	764	120	152	96	212	519
Mean (fertilized)		1222	869	777*	289	225	163*	215	

¹ All data averages of five replications except the two unfertilized plots.

* Significant at 5 percent level.

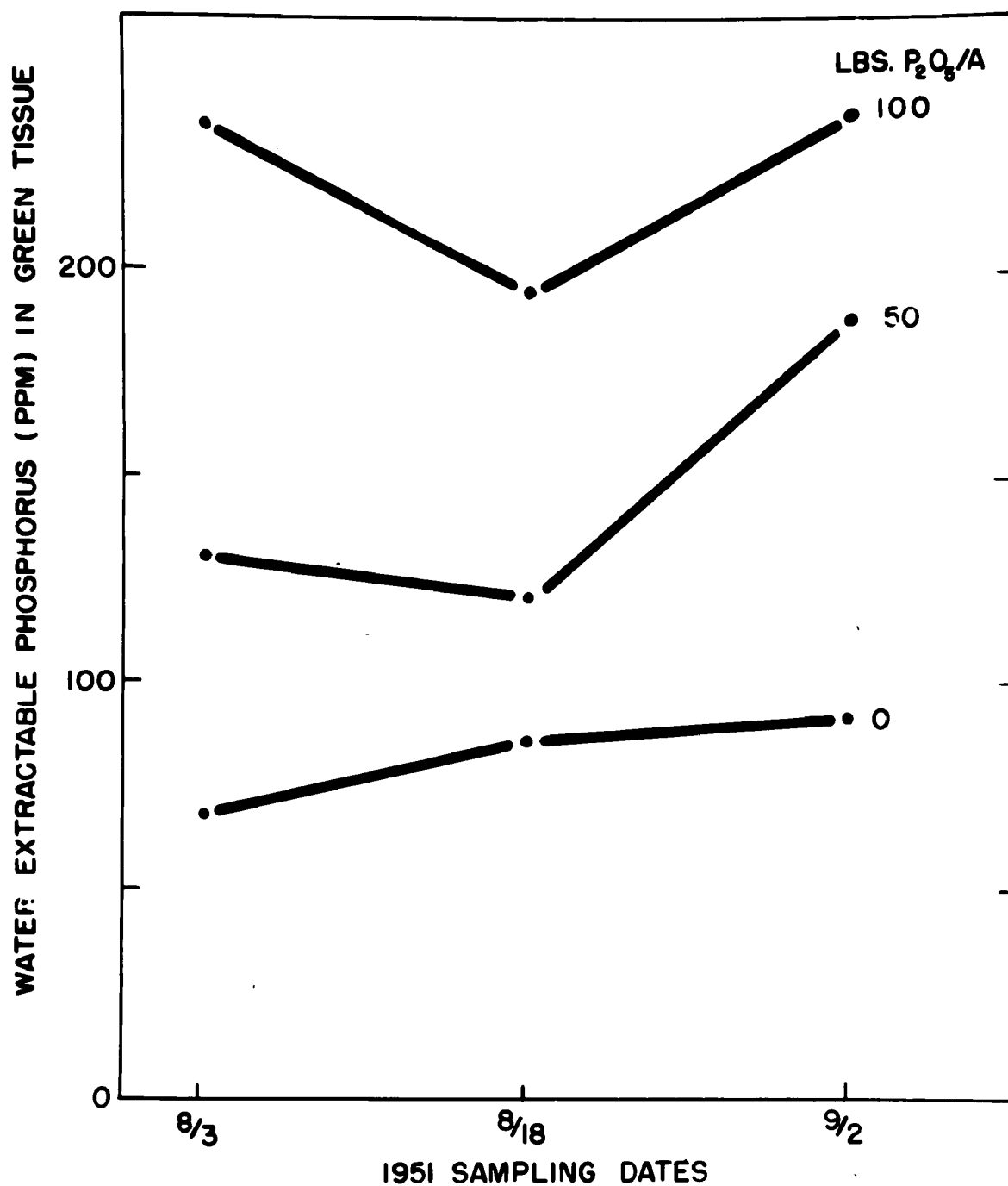


Figure 5. Seasonal changes in the concentration of water soluble phosphorus in peppermint stems as influenced by different amounts of phosphorus applied annually to an organic soil for a 10-year period.

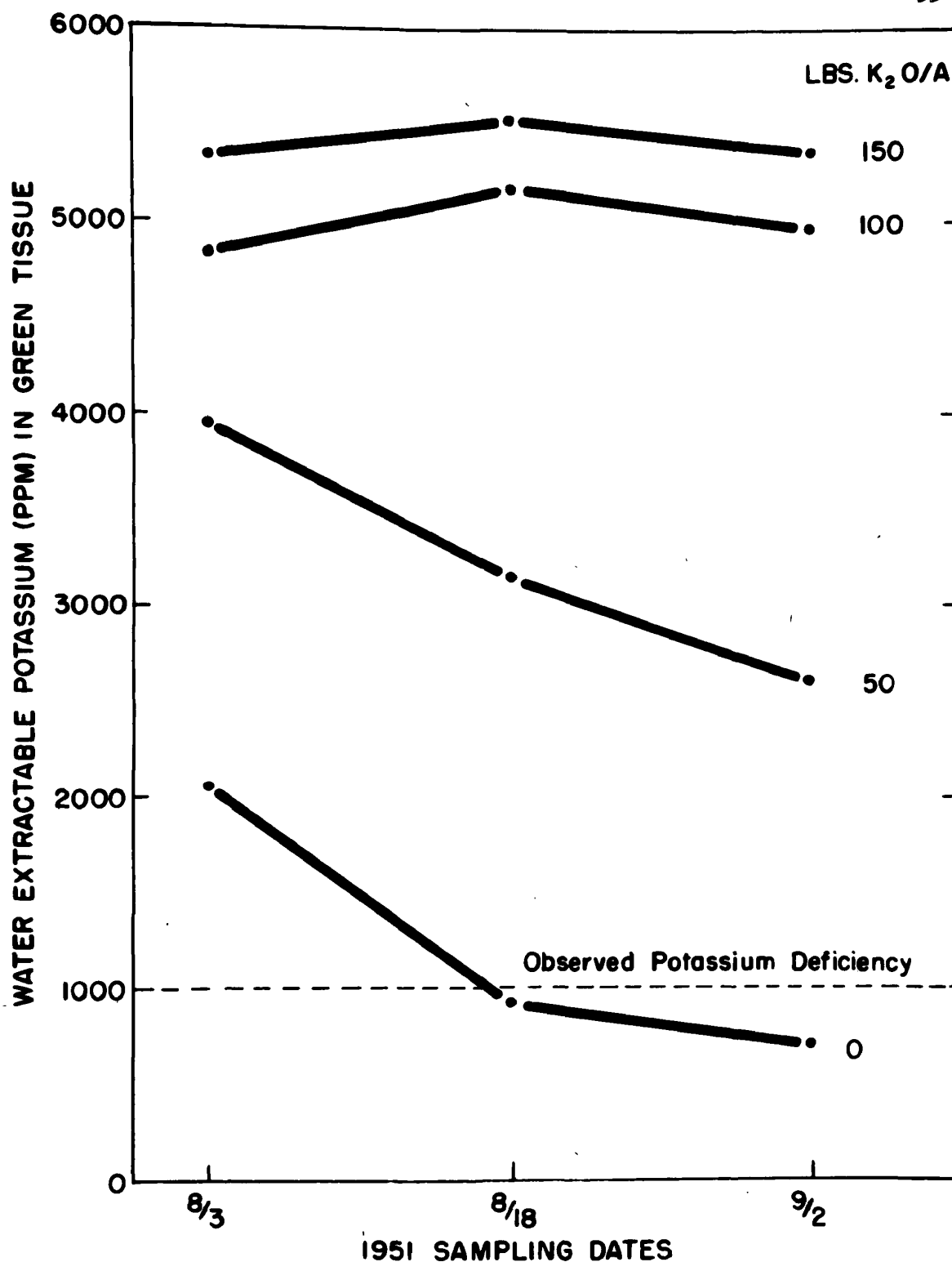


Figure 6. Seasonal changes in the concentration of water extractable potassium in peppermint stems as influenced by different amounts of potash applied annually to an organic soil for a 10-year period.

TABLE XIV

SEASONAL CHANGES IN THE CONCENTRATION OF WATER EXTRACTABLE NITRATE
IN PEPPERMINT AS INFLUENCED BY DIFFERENT AMOUNTS OF PHOSPHORUS
AND POTASH APPLIED ANNUALLY TO AN ORGANIC SOIL FOR A 10-YEAR PERIOD

Treatment*		Sampling date of 1951			Mean (season)
Fertilizer	Pounds per acre	8-3	8-18	9-12	
PPM extractable nitrate					
0-0-0	None	1300	1600	2080	1660
0-20-10	500	1968	1664	1632	1755
0-10-10	500	1992	1960	1560	1837
0-10-20	500	1792	1136	1208	1388
0-10-30	500	1864	1424	1216	1501
Mean (fertilized)		1904	1546	1404	

* All data averages of five replications except the two unfertilized plots.

The 1951 green-tissue tests with onion leaves in an additional experiment showed that the application of 50 pounds of nitrogen per acre at planting time caused a highly significant difference in the concentration of water soluble nitrate at the first sampling date (July 17), but no significant difference at the second sampling date (August 8), as shown in Table XV. There was a depression in the concentration of extractable potassium when nitrogen was applied, but the depression was not significant. The application of nitrogen caused little variation in the concentration of extractable phosphorus.

TABLE XV

THE INFLUENCE OF APPLIED NITROGEN ON THE CONCENTRATION OF WATER EXTRACTABLE NITRATE, PHOSPHORUS, AND POTASSIUM IN ONION LEAVES

Treatment* (1000 pounds) per acre	Sampling dates of 1951					
	7-17	8-8	7-17	8-8	7-17	8-8
	Nitrate		Phosphorus		Potassium	
	PPM of nutrient					
0-20-10	420	790	151	133	3328	2078
5-20-10	520	610	151	150	3049	1900
0-20-20	400	600	171	160	3258	2208
5-20-20	680	710	180	137	3162	2139
0-20-30	355	560	153	140	3360	2201
5-20-30	435	620	152	136	2974	2279
0-10-30	290	520	155	138	3409	2289
5-10-30	590	670	158	153	3437	2011
Mean						
No N	366	618	158	143	3249	2194
With N	556**	653	160	144	3156	2080

* All data averages of four replications.

** Significant at 1 percent level.

The data in Table XVI summarize the response of a number of crops to different phosphorus and potassium ratios. Crops in general grown on this organic soil respond to high potash ratios (0-1-2 and 0-1-3). However, onions and peppermint do best with the 0-1-1 and 0-2-1 ratios. Plots receiving phosphorus alone often produce lower yields of crops than the unfertilized plots due to the intensified potassium deficiency that results from such treatment.

In correlating soil tests and crop yields, consideration of the data from the single plots used for demonstration purposes was necessary for determining the relationship between extractable phosphorus and the yield of sugar beets and peppermint. For a nine-year period the soil of the demonstration plots had received 0, 25, 50 and 75 pounds of phosphate and a constant rate of 150 pounds of potash per acre. The amount of phosphorus removed from these soils by all of the four extractants was correlated with the yield of sugar beets and peppermint and was found to be significant in only one instance, as reported in Table XVII. A comparison of the extractable potassium and the yield of sugar beets and peppermint involved the data of three treatments replicated five times and one demonstration plot which had received 50, 100, 150 and 200 pounds of potash and a constant rate of 50 pounds of phosphate per acre for a nine-year period.

The correlation of extractable potassium and the yield of sugar beets was significant in one case (23 percent NaNO_3) when the three extractants were employed, but the relationship between extractable potassium and the yield of peppermint was not significant in any case, as shown in Table XVIII.

TABLE XVI

THE EFFECT OF FERTILIZER ON THE YIELD OF SEVERAL CROPS

Fertilizer*	Cabbage	Carrots	Celery	Potatoes	Onions	Brome Grass	Pepper- mint	Sugar beets	Soy- beans	Wheat
	Tons	Tons	Tons	Bushels	Bags	Tons	Pounds	Tons	Bu.	Bu.
0-20-10	24.1	24.3	20.6	428	382	2.1	21.7	11.6	38.6	32.0
0-10-10	22.4	23.8	18.0	437	254	2.2	21.0	11.1	39.1	35.4
0-10-20	24.1	25.1	21.7	508	304	2.6	21.9	13.9	41.3	38.3
0-10-30	24.4	26.1	22.7	531	328	2.6	18.9	14.5	41.8	40.2
0-0-30	2.5	19.5	5.5	337	151	1.4	9.4	6.2	33.1	11.0
0-20-0	1.3	9.0	7.7	100	281	1.1	11.4	3.1	10.7	5.3
None	1.0	10.5	3.0	103	31	0.9	8.9	3.2	17.7	7.3
Number of years	4	3	2	5	4	4	5	3	2	2

* One-thousand pounds per acre for cabbage, carrots, celery, potatoes, and onions; 500 pounds per acre for brome grass, peppermint, sugar beets, soybeans and wheat.

TABLE XVII

THE INFLUENCE OF DIFFERENT RATES OF APPLIED PHOSPHORUS ON THE YIELD OF SUGAR BEETS AND PEPPERMINT AND THE EXTRACTABLE PHOSPHORUS RECOVERED BY FOUR METHODS FROM THE 6-INCH DEPTH OF THE SOIL

Treatment ¹	Yield ²		Extractant			
	Sugar beets	Peppermint	0.018N CH ₃ COOH	0.135N HCl	0.025N HCl 0.03N NH ₄ F	0.1N HCl 0.03N NH ₄ F
	Tons per acre	Pounds oil per acre	Pounds extractable P ₂ O ₅ per acre			
0-0-30	6.2	9.4	1.5	20.0	43.5	42.4
0-5-30	15.7	14.1	2.4	27.5	57.3	57.0
0-10-30	15.8	18.9	4.0	36.6	57.3	74.4
0-15-30	16.1	19.7	8.5	70.5	58.4	93.8
r (yield vs extract- able P ₂ O ₅)		Sugar beets Peppermint	0.731 0.817	0.684 0.802	0.977* 0.876	0.270 0.949

¹ Yield data from single plots fertilized with 500 pounds per acre except the five replicated 0-10-30 plots of peppermint.

² Averages of 1949, 1950 and 1951, and 1947, 1949, 1950 and 1951 yields of sugar beets and peppermint, respectively.

** Significant at five percent level (0.950); for significance at one percent level r equals 0.990.

TABLE XVIII

THE INFLUENCE OF DIFFERENT RATES OF APPLIED POTASH ON THE YIELD OF
SUGAR BEETS AND PEPPERMINT AND THE EXTRACTABLE POTASSIUM
RECOVERED BY THREE METHODS FROM THE 6-INCH DEPTH OF THE SOIL

Treatment ¹	Yield ²		Extractant		
	Sugar beets	Peppermint	0.018N CH ₃ COOH	0.135N HCl	23% NaNO ₃
	Tons per acre	Pounds oil per acre	Pounds of extractable K ₂ O per acre		
0-10-10	11.1	21.0	35.4	82	67
0-10-20	13.9	22.9	70.0	155	167
0-10-30	14.5	18.9	107.8	213	223
0-10-40	16.1	18.4	204.0	--	324
r (yield vs ex- tractable K ₂ O)		Sugar beets	0.935	0.959	0.981*
		Peppermint	-0.735	-0.463	-0.669

¹ All data averages of five replications except the 0-10-40 single plot.

² Averages of 1949, 1950 and 1951, and 1947, 1949, 1950 and 1951 yields for sugar beets and peppermint, respectively.

* Significant at five percent level (2 df 0.950; 1 df 0.997).

The correlation of the water extractable phosphorus of the green-tissue and the yield of sugar beets was significant (Table XIX) for the 1951 yield as well as the 1949, 1950 and 1951 mean yield. The results of the demonstration plots were used in determining this correlation. The greatest seasonal variation in the concentration of water soluble phosphorus in the green-tissue occurred when no phosphate was applied to the soil.

The data of Table XX show a significant correlation for water extractable potassium and the 1949, 1950 and 1951 mean yield of sugar beets, but not for the 1951 yield. As the rate of applied potash was increased, the water soluble potassium in the green-tissue increased with a subsequent decrease in variability of the means.

In the case of peppermint as indicated in Table XXI the water extractable phosphorus was correlated with the yield and was found to be significant for the mean yield of 1947, 1949, 1950 and 1951, but not significant for the yield of 1951 which was probably due to crop failure on the 0-0-30 plot.

The water extractable potassium of the peppermint green-tissue and the yield of peppermint showed no significant correlation, as reported in Table XXII.

In comparing the relationship of soil tests and green-tissue tests with the yield of sugar beets and peppermint, a closer correlation existed for the green-tissue tests and yield than for the soil tests and yield.

TABLE XIX

THE INFLUENCE OF DIFFERENT RATES OF APPLIED PHOSPHORUS ON THE CONCENTRATION OF
WATER EXTRACTABLE PHOSPHORUS AND THE YIELD OF SUGAR BEETS

Treatment ¹	Sampling date of 1951							Percent error of mean	Tons per acre			
	7-11	7-23	8-3	8-18	9-2	9-18	10-13		1951	1949, 1950, 1951		
	PPM of water extractable phosphorus											
0-0-0	57	47	71	29	53	62	56	54 [†]	4.9	9.2	4.7	3.2
0-0-30	40	28	49	18	38	40	50	38 [†]	4.7	12.4	7.7	6.2
0-5-30	87	92	117	70	88	92	88	91 [†]	5.2	5.7	20.8	15.7
0-10-30	97	100	165	108	160	117	120	124 [†]	10.5	8.4	20.2	15.8
0-15-30	117	112	155	155	142	142	150	139 [†]	6.7	4.8	20.9	16.1
r (yield vs extractable phosphorus)											0.885*	0.879*

¹ All data from single plots fertilized with 500 pounds per acre except the two unfertilized plots.

* Significant at 5 percent level (0.878).

TABLE XX

THE INFLUENCE OF DIFFERENT RATES OF APPLIED POTASH ON THE CONCENTRATION OF
WATER EXTRACTABLE POTASSIUM AND THE YIELD OF SUGAR BEETS

Treatment ¹	Sampling dates of 1951					Mean	Percent error of mean	Tons per acre	
	7-11	7-23	8-3	8-18	9-2	9-18	10-3	1951	1949, 1950, 1951
PPM of water extractable potassium									
0-0-0	1912	930	772	387	231	562	552	764 [†]	219.2 28.7 4.7 3.2
0-10-10	3772	2037	1662	934	1009	946	999	1621 [†]	392.9 24.2 15.8 11.1
0-10-20	5165	3309	2418	2219	2426	2168	2488	2885 [†]	405.9 14.1 19.2 13.9
0-10-30	5178	4367	3278	3324	4728	4586	4824	4326 [†]	280.6 6.5 18.8 14.5
0-10-40	5588	4084	4200	4268	5810	6062	5520	5076 [†]	322.7 6.4 20.2 16.1
r (yield vs water extractable potassium)								0.855	0.921*

¹ All data averages of five replications except the 0-10-40 single plot.

* Significant at 5 percent level (0.878). For significance at 1 percent level r equals 0.959.

TABLE XXI

THE INFLUENCE OF DIFFERENT RATES OF APPLIED PHOSPHORUS ON THE
CONCENTRATION OF WATER EXTRACTABLE PHOSPHORUS AND THE YIELD OF
PEPPERMINT

Treatment ¹	Sampling dates of 1951				Percent error of mean	Pounds of oil per acre		
	8-3	8-18	9-2	Mean		1947, 1949, 1950, 1951		
						1951		
PPM extractable phosphorus								
0-0-0	68	85	91	81 [†]	6.1	7.5	2.1	8.9
0-0-30	49	49	73	57 [†]	8.0	14.0	0	9.4
0-5-30	100	80	135	105 [†]	5.1	4.8	8.2	14.1
0-10-30	112	113	185	137 [†]	24.2	17.6	11.0	18.9
0-15-30	145	135	217	166 [†]	25.8	15.5	10.4	19.7
r (yield vs water extractable phosphorus)							0.554	0.955*

¹ All data from single plots fertilized with 500 pounds per acre except for the five replicated 0-10-30 plots.

* Significant at 5 percent level (0.878); for significance at 1 percent level r equals 0.959.

TABLE XXII

THE INFLUENCE OF DIFFERENT RATES OF APPLIED POTASH ON THE CONCENTRATION OF WATER EXTRACTABLE POTASSIUM AND THE YIELD OF PEPPERMINT

Treatment ¹	Sampling dates of 1951				Percent error of mean	Pounds of oil per acre	
	8-3	8-18	9-2	Mean		1947,1949, 1950,1951	
						1951	1951
PPM extractable potassium							
0-0-0	2088	922	703	1238 [†] 430	34.7	2.1	8.9
0-10-10	3949	3147	2595	3230 [†] 367	11.3	14.3	21.0
0-10-20	4823	5170	4948	4980 [†] 101	2.0	17.2	22.9
0-10-30	5378	5527	5377	5427 [†] 50	0.9	11.0	18.9
0-10-40	5600	5840	7475	6305 [†] 589	9.3	5.6	18.4
r (yield vs water extractable potassium)						0.336	0.684 ²

¹ All data averages of five replications except the 0-10-40 single plot.

² For significance at 5 percent level r equals 0.878.

In correlating soil tests, green-tissue tests and crop yields, it was found that the extractable phosphorus and potassium in the soil and green tissue increased when the applied phosphorus and potassium was increased. Higher yields of sugar beets accompanied the increase of applied potassium, whereas the yield of peppermint oil was decreased when the rate of application exceeded 100 pounds per acre. Both crops showed little change in yield with the rate of phosphorus application varied.

Thus, in establishing optimum levels of plant nutrients for obtaining maximum yields with the aid of rapid soil tests and green-tissue tests, seasonal fluctuations in plant composition and crop response to the applied nutrients should be considered. When working with peppermint, it should be kept in mind that an increase in foliage yield is not necessarily accompanied by an increase in oil yield; in fact, the opposite situation will more likely occur.

Due to the limitations in the fertilizer analyses and rates in this experiment, it was impossible to establish optimum levels of phosphorus and potassium for maximum yields of sugar beets and mint.

SUMMARY

A study was made of the behavior of applied phosphorus and potassium in organic soil as indicated by soil tests and the relationship between soil tests, green-tissue tests, and crop yields. The results of the investigation are summarized as follows:

1. A highly significant correlation exists between the amount of phosphorus applied and the amount of phosphorus extracted from the soil by all of the following reagents; 0.025N HCl-0.03N NH_4F , 0.1N HCl-0.03N NH_4F , 0.135 N HCl, and 0.018N CH_3COOH . The correlation coefficients for these reagents were 0.943, 0.986, 0.915, and 0.967, respectively.

2. One drop of concentrated hydrochloric acid added to 10 milliliters of the soil extract when using 0.025N HCl-0.03N NH_4F as an extractant, was sufficient to properly acidify the medium for the molybdenum-blue phosphorus determination.

3. The amount of potash applied per acre shows a highly significant correlation with the amount of potassium extracted from the soil by any of the following reagents; 23 percent NaNO_3 , 0.135N HCl and 0.018N CH_3COOH . The correlation coefficients for these reagents were 0.640, 0.667, and 0.671, respectively.

4. Applied phosphorus remained principally in the surface soil while potassium was found throughout the 18-inch profile of the soil.

5. The extractable soil phosphorus expressed as P_2O_5 was a few pounds per acre higher in the fall samples while the extractable soil

potassium expressed as pounds of K_2O per acre was approximately doubled between fall and spring sampling.

6. Calcium and magnesium occurred uniformly throughout the experimental soil area.

7. The cation exchange capacity in the surface six-inches was 227 m.e. per 100 grams of soil. The exchangeable hydrogen slightly decreased while the percent base saturation and pH slightly increased with soil depth.

8. No appreciable variation in the properties of heat of wetting and the content of hygroscopic moisture occurred within the 18-inch profile.

9. Periodic green-tissue tests of sugar beets and peppermint in the summer of 1951 revealed a seasonal variation in the composition of water extractable nitrate, phosphorus and potassium in these plants.

10. Sugar beet and peppermint plants showing foliar symptoms of potassium deficiency contained 1800 ppm and 1000 ppm of that element, respectively.

11. Yield correlated better with green-tissue tests than with soil tests.

12. In correlating rapid soil tests, green-tissue tests, and crop yields, it was impossible to establish optimum levels of phosphorus and potassium for maximum yields of sugar beets and peppermint because of the following factors: the physiological nature of the plants, the seasonal variations in plant composition, the differential response of the crops to the fertilizer ratios, and the limitations in the fertilizer analyses and rates in this experiment.

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