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ABSTRACT

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The amount of soluble potassium retained by the exchange complex of soils receiving various applications of potash, superphosphate, lime and a mixture of minor elements was studied. Crop response from these treatments was observed on plots located on some representative soil series of the state. Following the field investigation, soil samples from some of the plots were taken into the laboratory and analyzed for exchangeable calcium, magnesium, potassium and hydrogen. Rapid soil tests were also used to estimate the available potassium and other ions held by the exchange complex of these soils.

Crop response varied with the different soils as well as with the various treatments. The field results, as a whole, emphasized the importance of providing a sufficient supply of the essential nutrients as a necessary factor in maintaining a fertile soil. The laboratory investigations demonstrated the effect of lime and superphosphate on the availability of potassium, and other cations. Superphosphate decreased the amount of applied potassium retained as the exchangeable form in the majority of the soils. The highest application of phosphorus and potash, in most instances, lowered the amount of exchangeable magnesium to a marked degree. The combined effects of lime and superphosphate also decreased the amount of applied potassium absorbed by the exchange complex of soils having a small amount of exchangeable hydrogen. The results of the rapid soil tests when compared to the exchangeable data gave a good indication

of the available plant food. The results of this study, in general, show that soils should be analyzed for all available nutrients, and if any are found to be deficient they should be supplied in quantities that will allow all the necessary elements to be available in sufficient quantities to produce good plant growth.

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A STUDY OF SOME OF THE FERTILITY FACTORS AFFECTING THE AVAILABILITY OF POTASSIUM APPLIED TO SOME MARYLAND SOILS

By
John Paul Wintermoyer

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INTRODUCTION

The maintenance of a sufficient supply of available potassium as well as other soluble nutrients is generally recognized as a good soil fertility practice. Potassium in an available form is needed to satisfy both the requirements of soils and crops. This available or exchangeable form of potassium is only one of the essential ions in the exchange complex of soils. The amount of this exchangeable element held by the colloidal complex may be greatly affected by the addition of other soluble nutrients. The removal of crops and loss by leaching are primarily responsible in causing a deficit in the supply of available plant food. This supply of available nutrients can be restored by the application of fertilizers. In Maryland, abnormal responses have been observed with potash fertilization. Potash treatments on soils deficient in available potassium as shown by the usual soil tests, produced excellent yields, while other soils showing similar needs gave no response. The response of crops to various applications of potash with and without other fertilizers, was observed in this investigation on various soil series through-out the state. The relation of exchangeable potassium to other exchangeable cations was studied with respect to its availability in proportion to other plant nutrients. An attempt was also made to estimate the potassium needs of some Maryland soils.

REVIEW OF LITERATURE

The availability of potassium in soils has been the subject of much investigation. Many investigators have related the availability of this element to a process in which replaceable potassium is converted to a fixed or non-replaceable form in soil. This has been demonstrated by the failure to recover potash applications as exchangeable potassium. Some investigators recognize an equilibrium between the replaceable and non-replaceable forms of potassium in which one form will revert to the other depending on the supply of each. Still other investigations have shown that individual ions, such as the PO_4 ion, soluble aluminum and available calcium are intimately associated with the solubility of potash. The exact nature of potash fixation is not definitely known, although many investigations have shown this phenomenon to be associated with the clay minerals or colloidal fraction of soils.

The fixation of potassium by mineral colloids as a result of alternate wetting and drying of soils, has been demonstrated by many workers (25,14,9,18,15,5). A mechanism of fixation by drying soils, in which the size of the ion and the contraction of the variable lattice of the montmorillonitic clay are important contributing factors, was proposed by Page and Baver (18). They found that the ionic sizes close to the size of certain free spaces within the lattice were closely correlated with susceptibility to fixation.

The non-exchangeable form of potassium as related to the crystalline clay colloids having definite lattice structure was investigated by other workers (25,15). Mineralogical studies, and chemical and x-ray analyses of soils receiving potash applications over a period of 50 years, led Volk (25) to conclude that a portion of the added potassium had reacted with colloidal silicates to form difficultly soluble muscovite. In general, the effect of wetting and drying of soils on the fixing of potash to a non-exchangeable form has been shown to be closely associated to the crystalline colloidal complex of the soils.

Since some soils exhibit a high amount of fixation while others do not, it has been advanced that an equilibrium exists between the replaceable potassium and the non-replaceable form (26,4, 2). The presence of a secondary material with the property of difficult replacement which can release potassium whenever the easily replaceable is lowered, or take it up as the easily replaceable potassium becomes too high has been suggested by Bray and DeTurk (4). Such an equilibrium is considered important in the potash economy of soils (26), since it is a means of conserving added potassium by holding it in forms which are relatively insoluble. These forms replenish the supply of replaceable potassium as it is depleted gradually by the growing crops.

Associated with the release of potassium from a non-replaceable form is the effect of freezing and thawing investigated by Fine, Bailey, and Truog (7). They worked with various clay minerals which had been subjected to potash fixation treatments previous to the freezing and thawing process. Most of the clay minerals investigated, allowed the release of considerable amounts of the non-exchangeable potassium.

Lime, in many instances (17,10,20,1,6), has been demonstrated to have a depressing effect on the solubility of potassium. The low productivity of high-lime soils of Iowa has been attributed in part to the relatively low amounts of exchangeable potassium. The investigations of Allaway and Pierre (1) showed that Iowa soils high in calcium carbonate have high potassium-fixing power which no doubt explains the small residual effects obtained from applications of potassium fertilizers. Work with muck soils by Enfield and Conner (6), however, showed the greatest amount of available potassium in the presence of lime than in its absence. This was true largely with soils having small amounts of inorganic material.

The lime-potassium problem was investigated by Jenny and Shade (13) who suggested the possibility of microbiological fixation of potash. They contend that calcium carbonate incorporated in the soil liberates adsorbed potassium which in turn may be absorbed by microorganisms. A similar suggestion was made by Blume and Purvis (3) who worked with coastal plain soils of Virginia. They found fixation was greatest in the Portsmouth soil which contains a high percentage of organic matter. Since the variation in the amount of potassium fixed at various samplings was so great, they suggested a microbiological activity factor as being largely responsible.

The effect of different ions on the conversion of soluble potassium to a non-available form has been investigated. Work on various prepared complexes of Fe, Al, Ca and Mg phosphates suggested to Joffe and Kolodny (14) that the PO_4 ion is in some manner responsible for the fixation of potassium. Their work with soils showed that the plot receiving acid phosphate alone, fixed the highest quantity of potassium. On the other hand, the soils which received annual applications of KCl or KCl + acid phosphate fixed the least.

The possibility of the aluminum ion affecting the fixation of potassium was studied by Volk (24). By removing the free alumina from various clays and minerals, the ability to fix potassium was decreased. Upon replacement of this alumina the fixing power was restored, which demonstrated that the aluminum ion may play a part in the availability of potassium.

A relation existing between the availability of potassium and the exchange capacity of soils was found by many workers (12,23,15,16). An equivalence between potash fixation and decrease in exchange capacity was found by Truog and Jones (23). A decrease in exchange capacity with potassium fixation was also noted by Joffe and Levene (16), but no equivalence was indicated. Contrary to these views, Wood and DeTurk (26) reported an increase in exchange capacity as a result of soluble potash reverting to a non-replaceable form.

Available potassium in Maryland soils was investigated by Thomas and Williams (22), using both quantitative and rapid chemical methods. A good agreement was found between exchangeable potassium and that determined by the rapid soil test. The influence of fertilizer treatments on the exchangeable potassium of some Maryland soils was studied by Thomas and Schueler (21). Their results indicate that the heavier soils were able to hold considerable amounts of exchangeable potassium while light textured soils retained smaller amounts. This was attributed to the low exchange capacity of the lighter soils. The effect of other ions on the retention of available potash was not considered in their work, nor was the effect of potash applications on other exchangeable cations of the sorption complex investigated.

According to the literature, it is conclusive that the availability of potassium in soils varies as a result of different existing soil conditions. Alternate wetting and drying of soils has been used to fix potassium to a non-replaceable form. This process is directly associated with the crystalline colloids or inorganic phase of soils. That the exchangeable and non-exchangeable forms of potassium exist in equilibrium with one another is also postulated. It is suggested that one form supplies the other depending on the amount of soluble potassium present. Different ions have been associated with the fixing of available potash. The PO_4 ion, calcium and free alumina have all been investigated as possible factors affecting available potassium. The investigators, however, did not consider the relation of these ions to one another as they affect the fertility level of soils.

EXPERIMENTAL PROCEDURE

The effect of phosphorus and lime on the availability of potassium was studied in this investigation. Various applications of superphosphate, ground limestone and muriate of potash were made on different soils in the state, and the response was measured in crop yields. Following the field investigations, soil samples were secured from some of the plots on the various soils used in the study. These were taken into the laboratory and the exchangeable calcium, magnesium, potassium and hydrogen were determined. The rapid soil tests developed at Maryland (22) were also used to estimate the amounts of the different available elements in these samples.

Plots were established in the spring of 1940 on 13 cooperating farms located in various parts of the state. An attempt was made to get as large a variety as possible of representative soil types. Table 1 gives the location and soil type of each farm. In order to study the effect of phosphorus on the solubility of potassium, various applications of different ratios of phosphoric acid and potash, as shown in Tables 2 and 3, were applied broadcast on the surface of the plowed soil and then were thoroughly worked in by discing. Phosphorus was applied as superphosphate (20%), and potassium was supplied as muriate of potash (60%). A mixture of minor elements was applied to each soil to see if any of the trace elements might be a limiting factor in plant growth. This mixture, prepared by the Research Foundation, Inc., New York, N.Y., included a total of 64 elements all of which had been found in plant life in minute quantities. Corn, with the exception of one crop of tomatoes, was grown on these plots the first season. In the fall of 1940, following the harvesting of the corn crop, a second application of the same amount and ratio of phosphoric acid and potash as given in Tables 4 and 5, was applied to each plot prior to the preparation of the seed bed for small grain. Barley or wheat was then planted and the yields were secured the following summer of 1941.

In order to study the effect of both phosphorus and calcium on the availability of potassium, additional sets of plots were established on three of the farms in the spring of 1941. Similar amounts and ratios of phosphoric acid and potash were applied to these plots in triplicate, and in addition some of them received applications of ground limestone. Treatments of the minor element mixture were also made on these farms. The amounts of these applications are shown in Tables 6 and 7. On Farm No. 6-B, the fertilizer was thoroughly worked into the plowed soil by discing, and the plots were planted to corn. The fertilizer on the other farms was applied on the surface of the soil and then plowed under. Corn was planted on Farm No. 2-B and soybeans were planted on Farm No. 13.

The results of the field tests are given in Tables 2,3,4,5,6 and 7. Tables 2 and 3 give the 1940 yields of tomatoes and corn. The barley and wheat yields of 1941 are found in Tables 4 and 5. Tables 6 and 7 give the corn and soybean yields for the plots on the farms receiving phosphoric acid, potash, and lime. Corn yields are reported in bushels of dry shelled corn (15% moisture) per acre, tomatoes are expressed in tons per acre, soybeans are reported in bushels of dry beans per acre, and wheat and barley are given in bushels of dry grain per acre. Straw yields are reported in tons per acre.

Following the field investigations, representative soil samples were secured from some of the plots and taken into the laboratory to be studied. The samples were first air dried, screened and then thoroughly mixed. All gravel, stones and organic fractions which did not pass through a ten-mesh screen were discarded.

The rapid soil tests as described by Thomas and Williams (22) were used to estimate the soluble calcium, magnesium, phosphorus, potassium, nitrates, ammonia, iron, aluminum, manganese, chlorine, carbonates, and sulfates. The pH value was obtained by the use of a Beckman pH meter (glass electrode) on a 3/2 soil/water mixture.

Exchangeable calcium, magnesium and potassium were determined on the leachate obtained by extracting 100 grams of ten-mesh soil with 600 ml. of normal neutral ammonium acetate. This extract was evaporated to dryness and the organic matter was destroyed with aqua regia. After removing the iron and aluminum with ammonia, the leachate was then made up to a definite volume. From this leachate calcium was determined by precipitating as the oxalate and titrating against standard potassium permanganate (8). The magnesium was precipitated with 8-hydroxyquinoline and titrated against standard potassium permanganate (8). Potassium was precipitated as the cobaltinitrite and titrated against standard potassium permanganate (19). Exchangeable hydrogen was extracted from a separate charge of soil using normal neutral ammonium acetate. This was done in a closed system to eleminate any possible change in the pH value of the extracting solution. After the soil was extracted, an aliquot of the leachate was titrated with standard sodium hydroxide using a Beckman pH meter. Exchangeable hydrogen was calculated from the amount of base necessary to bring the leachate back to the neutral point.

The results from the determinations of exchangeable calcium, magnesium, potassium and hydrogen are given in Tables 8 and 11. These are expressed in milliequivalents (m.e.) per 100 grams of soil. This enables one to compare the amount of one element with another. Since these four elements make up the greater portion of the cation exchange of Maryland soils, a column giving the total is found on each table.

The results of the rapid soil tests are reported in Tables 13 and 14. Since the soils contained no chlorine, sulfates or carbonates, these ions are omitted from the tables. The amounts of the various ions are not expressed quantitatively, since they are only estimates. For this reason, symbols are used to represent the relative amounts of the available elements. To obtain an average for triplicate results, a numerical value was given to each symbol and an average was thereby calculated. The following meanings are given to each symbol:

- \- None
- + Detectable
- T Very small amount
- L Small amount
- M Medium amount
- H High amount
- X Very high amount

DISCUSSION

Although the data are more or less self explanatory, the following discussion is given to emphasize the points of greatest importance. For convenience the discussion of the data is divided into two headings, the Field Data and the Laboratory Data. The Field Data include the crop yields obtained from the fertilizer investigations with plots located on 13 farms through-out the state. The yields are discussed with reference to the response of crops to various treatments of potash as affected by amendments of phosphorus and lime. The Laboratory Data include the results from the chemical analyses made on soil samples taken from some of the plots of the field investigation. These data show the effect of the fertilizer treatments on the amount of exchangeable potassium and other cations held by the exchange complex of the soils used in this study.

Field Data:

Tables 2 and 3 give the tomato and corn yields for 1941. The yields of tomatoes (Table 2) were significantly better from the 100, 200, 400 and 500 pound treatments of potash when compared to the check plot No. 13. Equally as good a yield was obtained from Plot 11 which received 500 pounds each of K_2O and P_2O_5. In general, the soil in these plots showed a definite response to potash as expressed in both the yield and quality of tomatoes. Since tomatoes are heavy feeders on potassium, one might expect a large percentage of the potash applied on plots 14,15,16 and 17 to be held in the exchangeable form. Replaceable potassium in a Sassafras sandy loam was found by Hester and Shelton (11) to be a good index of the potassium available to tomatoes.

The corn yields of Table 3 show no significant increase above the check plots as a result of potash fertilization alone. Farm No. 2-A is an exception and show a definite response to potassium. The highest yields for each farm are usually associated with combination treatments of phosphorus and potash. The average of the corn yields in Table 3 show no significant difference between plots. One can assume from these results that an adequate level of plant nutrients is necessary for good crop production, and it is difficult to measure the influence of a single element by means of crop yields.

The minor element treatment of 150 pounds per acre on plot 12 when compared to plot 6 of Table 2 showed a marked increase in the yield of tomatoes on Farm No. 1-A. The corn yields in Table 3 indicated irregular responses from the trace elements. Farms No. 5 and 7 made noticeable increases above the yields of plot 6. The minor element treatment on the majority of the farms growing corn showed little increase in yield. The response of tomatoes was, however, significant although the yields were not as large as some of the heavy potash treatments.

The 1941 barley and wheat yields obtained from the second application of phosphoric acid and potash, as given in Tables 4 and 5, indicate responses similar to the corn yields of Table 3. The extremely poor yields obtained from Farm No. 1-B is attributed primarily to late planting and a poor stand. No one treatment gave consistently high results with all farms. In general, the larger yields for most farms were obtained from treatments of both phosphorus and potash or from phosphorus alone. The averages for the barley and wheat yields also show the same effect. This leads one to believe that superphosphate and sometimes potash corrected the limiting factors in the growth of the small grain crops.

Tables 6 and 7 give the yields of corn and soybeans from plots receiving phosphorus, potash, lime and the minor element mixture. The fertilizer on Farm No. 6-B was disced into the surface of the plowed soil, while the fertilizer on Farm No. 2-B was plowed under. There were no indications of salt injury since the yields were larger on Farm No. 6-B. A response with corn was not obtained from all lime treatments. However, the largest yields for each farm was obtained from a treatment of equal quantities of phosphorus and potash, and two tons of limestone. The corn crops on both farms were affected by drought, and lack of moisture may have been a limiting factor in crop growth. The effect of the minor element treatments produced no noticeable increase in the crop yields. Soybeans in every instance (Table 7) responded to the application of limestone. The largest average yield of beans was obtained from an application of 100 pounds of P_2O_5, 500 pounds of K_2O and two tons of ground limestone. From these data, a sufficiency of available potassium and calcium appear to be very essential in the production of a legume, such as soybeans.

The field data, in general, do not show a decided response of crops to potash treatments alone. The results demonstrate the necessity of a sufficient level of required nutrients for good crop production. A deficient element may be a limiting factor in many instances, but this deficiency may be caused, in part, by the excess of another element which may affect its availability in the soil. Thus, in attempting to restore fertility of a soil, an inventory should be made of the nutrient supply. Deficient elements must be supplied in sufficient quantities, but not to an excess as to cause them to be a limiting factor in the availability of another.

Laboratory Data:

The amounts of exchangeable calcium, magnesium, potassium and hydrogen in the soils receiving phosphoric acid and potash treatments are given in Table 8. The effect of these treatments on the exchangeable calcium can be seen by comparing the values with the untreated plot 13. Superphosphate increased, in most instances, the exchangeable calcium. No doubt this was supplied from the calcium contained in superphosphate. Potash alone, plot 17, showed a depressing effect on the exchangeable calcium as a result of the displacing power of the potassium ion. The effect of one counterbalances the effect of the other to some extent when both superphosphate and potash are applied. The importance of calcium in the exchange complex of soils is demonstrated in Table 9. In most of these soils, this element occupies from 50% to 60% of the sorption complex.

The most noticeable effect of these fertilizer treatments on the exchangeable magnesium is found with plot 11 which received on most farms, a total of 1000 pounds each of P_2O_5 and K_2O. In many instances the amount of exchangeable magnesium was decreased over 50% when compared to the check plot 13. This loss of magnesium was not as large on plot 17 which received, usually, a total of 1000 pounds of K_2O. These data indicate that the calcium of superphosphate when applied in addition to heavy applications of potash caused a decrease in the exchangeable magnesium. This exemplifies the displacing power of high applications of fertilizers and the possible depletion of this essential element when proper amendments of magnesia or dolomite are not made.

The variation of exchangeable hydrogen with different treatments for each soil was not consistent. There was no definite correlation between the exchangeable hydrogen and amount of potassium made available. Hydrogen in many of the soils occupied a large portion of the exchange complex. As shown in Table 9, values for the more acid soils ranged from 40 to 45 percent to 15 and 20 percent in the less acid soils.

Exchangeable potassium is given in Table 10 in pounds of K_2O per acre. The effect of superphosphate additions alone, plot 7, can be seen by comparing it with check plot 13. Superphosphate when applied alone showed little effect on the amount of exchangeable potassium in the soils on these farms. However, on Farms 4, 8, and 10, there was a decrease in the amount of this exchangeable ion. Of particular interest is the comparison of plot 11 with plot 17. Plot 11 which received a total of 1000 pounds each of P_2O_5 and K_2O has, in every soil, less exchangeable potassium than plot 17 which received only the 1000 pounds of K_2O. This indicates the possibility of a conversion of soluble potash to a non-exchangeable form in some of the soils in this study. The data in Table 10 also include the percent of the potash in each application that was absorbed by the exchange complex of these soils. This calculation did not consider the differences in crop yield as a factor affecting the percent of the applied potassium that was absorbed. The percentages were obtained in the following manner:

$$\frac{\text{Pounds of Exchangeable } K_2O \text{ found} - \text{Pounds of exchangeable } K_2O \text{ in check Plot 13}}{\text{Pounds of } K_2O \text{ supplied in the fertilizer treatment}} = \% \text{ of applied } K_2O \text{ absorbed}$$

In many instances, only 50 to 70 percent of the applied potassium was absorbed by the soils which received 1000 pounds each of P_2O_5 and K_2O. The average percent values for eight of the farms in Table 10 show almost a complete recovery of the potash applied alone on plot 17, while only

70 per cent was absorbed by the exchange complex of the soil in plot 11. A similar effect was produced by a comparable treatment on plot 8. Superphosphate which was supplemented with potash in these treatments, appears to have a depressing effect on the sorption of the potassium. This is in agreement with the findings of Joffe and Kolodny (14) who associate the PO_4 ion with the fixation of potassium. The extent to which this decrease in available potassium is found in different soils is shown by examining each farm. The soil on Farms No. 3 and 4 retained the greatest portion of the applied potash in the exchangeable form. These soils were the Frankstown and Montalto series respectively, which have a heavy texture. The remaining soil series exhibited varying degrees of potash sorption as affected by superphosphate treatments. Of particular interest are the soils on Farms No. 9 and 11 which retained a very small percentage of the applied potash as exchangeable potassium. This was true both in the presence and absence of superphosphate. The soil on Farm No. 9 was a sandy loam having a low exchange capacity, and the soil on Farm No. 11 had its exchange complex highly saturated with calcium and magnesium. These may have been the limiting factors causing the low percentage of absorbed potassium.

The combined effects of phosphorus and calcium on the availability of potassium are given in Tables 11 and 12. The averages of the exchangeable data, Table 11 (Cont.), show that the amounts of exchangeable calcium and magnesium were increased as a result of limestone additions. There was also a corresponding decrease in the exchangeable hydrogen. This is to be expected since calcium and magnesium could enter the exchange complex to displace the exchangeable hydrogen. The effect of these treatments on the exchangeable potassium, in Table 12, is very similar to some of the results given in Table 8. Since all of the applied potash was not recovered as exchangeable potassium on the majority of the plots receiving 500 pounds of K_2O, it is suggested that a part of the soluble potassium in these treatments had been converted to a non-replaceable or fixed form. This is very true with the limed plots on soils having a comparatively low percentage of exchangeable hydrogen (Table 12). On Farm No. 13, the lime was apparently active in displacing the exchangeable hydrogen of the complex rather than entering into a fixation reaction with soluble potassium as postulated by some investigators (1,6,20).

The effect of the minor element treatments on the exchangeable cations of these three soils is shown in Table 11. The plot receiving the minor element mixture when compared to a check plot, produced no differences in the amount amount and proportions of the replaceable elements.

The use of the rapid soil tests as a means of indexing the supply of available ions is given in Tables 13 and 14. These tests for available calcium, magnesium, and potassium agree very well with the exchangeable data. The pH values when compared to the percent of the exchange complex occupied by hydrogen indicate some agreement. The amount of available phosphorus was not determined in this study by a quantitative method, but the rapid method has been shown by Thomas and Williams (22) to give a good indication of the amount of this element. In general, the rapid soil tests give a good indication of the available potassium and other elements absorbed by the exchange complex of the soils used in this investigation.

From a practical standpoint, this investigation demonstrates the necessity of providing a sufficient amount of available plant nutrients for the maintenance of a fertile soil. The amount of available potassium in this study varied with different soils and different fertilizer treatments. An application of 500 pounds each of P_2O_5 and K_2O lowered the amount of exchangeable magnesium. To prevent a magnesium deficiency, as a result of heavy fertilization, soluble magnesia amendments should be made. This same fertilizer treatment decreased the percent of applied potassium absorbed by the complex of most of the soils studied. When superphosphate is needed by these soils, extra potash must be applied in order to compensate for the potassium that will be converted to a non-exchangeable form. Lime should be supplied in sufficient quantities to neutralize soil acidity and to correct a calcium deficiency. An excess, however, may affect the availability of potassium. In general, a soil analysis should be made to detect deficient elements, and these tests must be supplemented with a fertilizer recommendation that will restore the soil with a sufficiency of available plant food.

TABLE 1. The Farm Number, Location and Soil Type of Farms Cooperating in the Project.

Farm No.	Location	Soil Type
1-A	Chestertown-Kent Co.	Sassafras Silt Loam (Butlertown)
1-B	Chestertown-Kent Co.	Sassafras Silt Loam (Butlertown)
2-A	Chestertown-Kent Co.	Sassafras Silt Loam
2-B	Chestertown-Kent Co.	Sassafras Silt Loam
3	Williamsport-Washington Co.	Frankstown Silt Loam
4	Churchville-Harford	Montalto Clay Loam
5	Rocks-Harford Co.	Chester Loam
6-A	Ashton-Montgomery Co.	Manor Loam
6-B	Ashton-Montgomery Co.	Manor Loam
7	Mt. Airy-Carroll Co.	Manor Gravelly Loam
8	Jarrettsville-Harford Co.	Manor Loam (Glenelg)
9	Salisbury-Wicomico Co.	Keyport Sandy Loam
10	Germantown-Montgomery Co.	Chester Loam
11	Knoxville-Frederick Co.	Ashe Loam (Myersville)
12	Hagerstown-Washington Co.	Hagerstown Silt Loam
13	Spencerville-Montgomery Co.	Sassafras Fine Sandy Loam

TABLE 2. The 1940 Yield of Tomatoes Obtained from Cooperative Farm Plots Receiving Different Amounts of Phosphoric Acid, Potash and Minor Element Mixture.

	Fertilizer Treatment Pounds Per Acre			Tomato Yields in Tons per Acre
Plot No.	P_2O_5	K_2O	Minor Element Mixture	Farm No. 1-A
				Tons
1	160	----	----	7.85
2	160	100	----	6.98
3	160	200	----	9.32
4	160	400	----	7.87
5	500	----	----	8.90
6	70	30	----	4.54
7	80	----	----	5.40
8	80	100	----	7.91
9	80	200	----	5.45
10	80	400	----	8.25
11	500	500	----	10.37
12	70	30	150	8.87
13	----	----	----	6.91
14	----	100	----	11.75
15	----	200	----	9.49
16	----	400	----	9.49
17	----	500	----	10.76

TABLE 3. The 1940 Yields of Corn Obtained from the Cooperative Farm Plots Receiving Different Amounts of Phosphoric Acid, Potash and Minor Element Mixture.

	Fertilizer Treatment Pounds per Acre			Corn Yields in Bushels Shelled Corn per Acre by Farm Numbers					
Plot No.	P_2O_5	K_2O	Minor Element Mixture	1-B	2-A	3	4	5	7
				Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	160	---	---	71.3	65.9	67.4	68.0	65.2	80.0
2	160	100	---	48.8	58.9	67.4	66.1	73.2	74.6
3	160	200	---	72.8	61.0	62.2	72.6	65.6	58.1
4	160	400	---	67.9	66.3	70.3	67.8	51.8	66.2
5	500	---	---	72.8	60.7	65.4	62.6	59.9	68.9
6	70	30	---	79.5	51.8	75.6	59.5	49.6	63.8
7	80	---	---	82.9	55.4	76.8	53.2	73.7	72.6
8	80	100	---	35.1	69.2	67.4	56.4	66.5	65.8
9	80	200	---	45.5	68.6	64.2	66.5	71.4	51.6
10	80	400	---	51.0	51.8	65.8	72.0	54.0	55.9
11	500	500	---	40.5	65.7	61.1	66.9	64.3	67.5
12	70	30	150	65.8	55.4	68.7	62.8	61.6	73.2
13	---	---	---	74.6	59.2	72.7	47.5	66.1	68.9
14	---	100	---	67.9	52.7	61.4	58.0	71.9	72.2
15	---	200	---	70.9	61.0	73.9	70.0	58.0	54.5
16	---	400	---	70.9	54.1	69.9	63.9	66.1	50.5
17	---	500	---	63.6	64.8	68.7	61.7	52.2	62.1

TABLE 3 (Cont.). The 1940 Yields of Corn Obtained from the Cooperative Farm Plots Receiving Different Amounts of Phosphoric Acid, Potash and Minor Element Mixture.

Plot No.	Fertilizer Treatment Pounds per Acre P_2O_5	K_2O	Minor Element Mixture	Corn Yields in Bushels of Shelled Corn per Acre by Farm Numbers. 8	9	10	11	12	Average
				Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	160	—	—	65.1	49.8	78.0	83.8	22.5	64.1
2	160	100	—	55.0	56.2	71.6	68.3	27.6	60.3
3	160	200	—	49.3	51.2	69.0	67.9	17.3	58.8
4	160	400	—	48.3	44.9	80.1	66.8	29.1	60.0
5	500	—	—	47.8	46.9	90.7	68.6	31.9	59.6
6	70	30	—	49.6	42.2	87.3	86.3	26.3	61.1
7	80	—	—	57.2	51.8	73.0	79.9	23.3	63.7
8	80	100	—	60.6	48.6	71.1	72.0	28.1	57.7
9	80	200	—	44.9	52.6	71.4	65.4	16.9	56.1
10	80	400	—	59.1	46.5	75.3	67.1	26.6	56.8
11	500	500	—	56.9	42.2	89.9	61.7	31.5	59.2
12	70	30	150	48.9	42.6	75.3	89.1	25.1	60.8
13	—	—	—	47.8	51.6	69.2	83.3	24.0	60.8
14	—	100	—	58.4	43.9	—	83.8	32.6	59.9
15	—	200	—	66.3	50.5	71.4	75.8	24.4	61.5
16	—	400	—	56.7	43.8	74.0	83.3	27.0	60.0
17	—	500	—	35.4	55.0	76.8	84.4	29.6	58.7

TABLE 4. The 1941 Yields of Barley Obtained from the Cooperative Farm Plots Receiving the Second Application of Phosphoric Acid and Potash.

Plot No.	Fertilizer Treatment Pounds Per Acre		Barley Yields Per Acre by Farm Numbers					
	P_2O_5	K_2O	Farm No. 3		Farm No. 10*		Average	
			Bu. Grain	Tons Straw	Bu. Grain	Tons Straw	Bu. Grain	Tons Straw
1	160	---	34.6	0.88	45.0	1.13	39.8	1.00
2	160	100	31.5	0.88	37.1	0.90	34.3	0.89
3	160	200	27.7	0.76	36.5	0.94	32.1	0.85
4	160	400	26.9	0.83	45.4	1.17	36.1	1.00
5	500	---	33.5	0.85	54.2	1.43	43.9	1.14
7	80	---	30.8	0.83	33.8	0.67	32.3	0.75
8	80	100	27.7	0.77	39.0	0.78	33.4	0.78
9	80	200	31.3	0.99	41.3	0.89	36.3	0.94
10	80	400	27.9	0.82	43.5	1.00	35.7	0.91
11	500	500	32.5	1.10	45.6	1.11	39.1	1.11
13	---	---	25.8	0.75	42.1	1.02	34.0	0.89
14	---	100	38.5	1.21	39.0	0.96	38.8	1.09
15	---	200	32.6	0.85	46.9	1.12	39.8	0.99
16	---	400	20.6	0.71	42.5	1.05	31.6	0.88
17	---	500	31.5	0.98	47.1	1.40	39.3	1.19

* Plots on this farm did not receive the second application of fertilizer.

TABLE 5. The 1941 Yields of Wheat Obtained from the Cooperative Farm Plots Receiving the Second Application of Phosphoric Acid and Potash.

Plot No.	Fertilizer Treatment Pounds Per Acre		Wheat Yields Per Acre by Farm Numbers							
	P_2O_5	K_2O	Farm No. 1-B		Farm No. 2-A		Farm No. 4		Farm No. 5	
			Bu. Grain	Tons Straw	Bu. Grain	Tons Straw	Bu. Grain	Tons Straw	Bu. Grain	Tons Straw
1	160	---	6.7	0.38	21.3	0.94	31.2	1.41	20.3	1.55
2	160	100	5.2	0.33	22.5	0.99	30.5	1.32	22.8	1.29
3	160	200	7.2	0.37	19.2	0.94	37.3	1.55	26.8	1.52
4	160	400	6.3	0.41	22.8	1.02	33.7	1.53	22.8	1.46
5	500	---	10.2	0.53	21.0	1.05	30.3	1.33	30.3	1.47
7	80	---	8.7	0.50	24.5	1.13	39.2	1.59	17.8	1.17
8	80	100	6.8	0.46	23.8	1.07	34.0	1.48	17.5	1.07
9	80	200	6.0	0.32	26.5	1.38	34.5	1.55	15.0	1.04
10	80	400	8.2	0.38	19.8	1.03	30.7	1.36	20.7	1.32
11	500	500	9.8	0.43	19.7	1.07	30.5	1.31	18.5	1.17
13	---	---	9.3	0.66	22.3	1.19	22.2	0.99	18.0	1.25
14	---	100	11.0	0.70	22.8	1.14	28.2	1.12	20.3	0.68
15	---	200	11.0	0.78	22.2	1.05	29.5	1.28	18.5	1.32
16	---	400	13.3	0.89	21.8	1.15	28.2	1.16	18.7	1.08
17	---	500	10.2	0.63	27.0	1.30	25.7	1.11	22.3	1.34

TABLE 5 (Cont.) The 1941 Yields of Wheat Obtained from the Cooperative Farm Plots Receiving the Second Application of Phosphoric Acid and Potash.

Plot No.	Fertilizer Treatment Pounds Per Acre		Wheat Yields Per Acre by Farm Numbers							
	P_2O_5	K_2O	Farm No. 6-A		Farm No. 7		Farm No. 8		Average	
			Bu. Grain	Tons Straw	Bu. Grain	Tons Straw	Bu. Grain	Tons Straw	Bu. Grain	Tons Straw
1	160	---	26.5	1.07	46.5	2.14	43.3	2.36	26.5	1.41
2	160	100	31.3	1.65	41.3	2.10	32.8	1.63	26.6	1.33
3	160	200	24.0	1.35	31.8	1.73	14.9	0.86	23.0	1.19
4	160	400	27.0	1.18	29.8	1.42	20.7	0.83	23.6	1.12
5	500	---	28.2	1.27	42.3	1.85	33.8	1.50	28.0	1.29
7	80	---	24.5	1.12	25.2	2.93	44.2	2.10	26.0	1.51
8	80	100	28.2	1.29	32.5	1.84	40.0	2.09	26.1	1.33
9	80	200	22.5	1.08	31.0	1.70	24.8	1.11	22.9	1.17
10	80	400	22.0	1.01	29.2	1.33	22.5	0.97	21.9	1.06
11	500	500	26.0	1.36	40.5	1.94	30.5	1.16	25.1	1.21
13	---	---	24.0	1.04	38.2	1.77	27.8	1.53	23.1	1.20
14	---	100	22.5	1.45	37.0	1.85	31.3	1.72	24.7	1.24
15	---	200	30.8	1.30	30.3	1.75	20.0	0.96	23.2	1.21
16	---	400	17.5	0.76	27.0	1.27	18.7	0.81	20.7	1.02
17	---	500	22.0	1.02	27.2	1.29	20.5	0.80	22.1	1.07

TABLE 6. The 1941 Yields of Corn Obtained from Cooperative Farm Plots Receiving Different Amounts Of Phosphoric Acid, Potash, Lime and Minor Element Mixture.

Fertilizer Treatment Pounds Per Acre			Yields Given in Bushels Shelled Corn Per Acre													
			Farm No. 6-B							Farm No. 2-B						
P_2O_5	K_2O	Ground Limestone	Plot No.	Corn Bu.	Plot No.	Corn Bu.	Plot No.	Corn Bu.	Average Bu.	Plot No.	Corn Bu.	Plot No.	Corn Bu.	Plot No.	Corn Bu.	Average Bu.
—	—	—	1	33.8	12	35.4	23	44.9	38.0	—		—		—		—
100	—	—	2	47.6	13	38.6	24	43.6	43.3	—		—		—		—
—	100	—	4	51.7	15	49.8	26	24.7	42.1	—		—		—		—
100	100	—	3	54.4	14	42.7	25	40.1	45.7	1	39.8	11	31.9	21	21.0	30.9
100	100	4000	8	37.3	19	41.3	30	55.8	44.8	2	45.6	12	35.2	22	33.5	38.1
500	—	—	5	50.0	16	49.4	27	36.4	45.3	—		—		—		—
—	500	—	7	21.0	18	50.9	29	37.6	36.5	—		—		—		—
100	500	—	—		—		—		—	3	33.9	13	39.1	23	32.7	35.2
100	500	4000	—		—		—		—	4	26.0	14	23.7	24	21.6	23.8
500	100	—	—		—		—		—	5	23.7	15	34.4	25	14.0	24.4
500	100	4000	—		—		—		—	6	26.2	16	23.7	26	20.8	23.6
500	500	—	6	46.6	17	47.4	28	36.6	45.5	7	29.4	17	24.4	27	11.8	21.9
500	500	4000	9	61.4	20	61.0	31	44.9	55.8	8	37.5	18	35.5	28	18.9	30.6
—	—	—*	11	40.7	22	40.0	33	44.8	41.8	—		—		—		—
100	100	—*	—		—		—		—	10	39.9	20	19.6	30	27.6	29.0

* This plot received in addition 400 pounds of a Minor Element Mixture.

TABLE 7. The 1941 Yields of Soybeans Obtained from Cooperative Farm Plots Receiving Different Amounts of Phosphoric Acid, Potash, Lime and Minor Element Mixture.

Fertilizer Treatment Pounds per Acre			Yield of Beans and Straw from Farm No. 13									Average	
P_2O_5	K_2O	Ground Limestone	Plot No.	Beans Bu.	Straw Tons	Plot No.	Beans Bu.	Straw Tons	Plot No.	Beans Bu.	Straw Tons	Beans Bu.	Straw Tons
100	100	----	1	10.8	1.89	11	15.4	1.71	21	9.2	1.79	11.8	1.79
100	100	4000	2	14.6	1.97	12	13.1	1.83	22	13.5	1.88	13.8	1.89
100	500	----	3	15.0	1.75	13	14.0	1.64	23	12.3	1.53	13.8	1.64
100	500	4000	4	16.3	2.06	14	16.7	1.95	24	18.8	1.73	17.2	1.91
500	100	----	5	10.2	1.26	15	11.9	2.06	25	10.8	1.34	11.0	1.55
500	100	4000	6	15.0	2.11	16	13.8	2.31	26	19.2	1.86	16.2	2.09
500	500	----	7	10.2	1.48	17	11.5	1.95	27	18.1	1.86	13.3	1.76
500	500	4000	8	18.3	2.11	18	14.8	2.36	28	9.6	1.60	14.2	2.02
100	100	----*	10	13.1	1.43	20	6.5	1.21	30	8.1	1.59	9.2	1.41

* This treatment received in addition 400 pounds of Minor Element Mixture.

TABLE 8. The Milliequivalents of Exchangeable Calcium, Magnesium, Potassium, and Hydrogen Found in the Soil from Cooperative Farm Plots Receiving Phosphoric Acid and Potash.

Plot No.	Fertilizer Treatment Total lbs. Per Acre P_2O_5	K_2O	The Milliequivalents of Exchangeable Cations per 100 Grams of Soil for the Respective Farm Numbers. Ca	Mg	K	H	Total m.e.	Ca	Mg	K	H	Total m.e.
			Farm No. 1-B					Farm No. 2-A				
7	160	---	4.04	0.87	0.15	2.33	7.39	4.39	0.24	0.15	1.76	6.54
8	160	200	4.01	0.90	0.30	2.23	7.44	4.00	0.62	0.30	2.15	7.07
10	160	800	3.55	0.71	1.10	2.02	7.38	3.72	0.29	0.80	2.62	7.43
11	1000	1000	4.66	0.31	0.55	2.42	7.94	4.22	0.10	0.65	2.42	7.39
13	----	----	3.87	0.95	0.15	2.21	7.18	3.52	0.71	0.15	2.08	6.46
17	----	1000	2.86	0.61	1.30	2.03	6.80	3.11	0.36	1.10	1.91	6.48
			Farm No. 3					Farm No. 4				
7	160	---	9.55	0.54	0.25	1.23	11.57	9.10	2.33	0.20	1.56	13.19
8	160	200	5.51	0.47	0.50	2.33	8.81	8.60	2.37	0.80	2.38	14.15
10	160	800	4.77	0.49	1.40	3.66	10.32	7.24	2.01	1.60	2.08	12.93
11	1000	1000	6.63	0.17	1.30	4.29	12.39	8.49	1.25	1.40	2.84	13.98
13	----	----	5.48	0.48	0.25	2.45	8.66	7.88	2.45	0.40	1.73	12.46
17	----	1000	5.35	0.52	1.70	3.14	10.71	7.22	1.92	1.75	2.29	13.18
			Farm No. 5					Farm No. 6-A				
7	160	---	5.02	1.13	0.20	1.70	8.05	3.27	0.20	0.10	2.90	6.47
8	160	200	4.72	1.09	0.40	1.82	8.03	3.63	0.12	0.15	3.26	7.16
10	160	800	4.58	0.92	1.05	2.02	8.57	3.25	0.13	0.70	3.50	7.60
11	1000	1000	5.99	0.64	0.95	2.59	10.17	3.93	0.08	0.65	3.10	7.76
13	----	----	4.33	1.03	0.20	2.39	7.95	3.76	0.24	0.10	3.45	7.55
17	----	1000	4.25	0.81	1.30	2.48	8.84	3.16	0.17	0.80	3.56	7.49
			Farm No. 7					Farm No. 8				
7	160	----	8.13	1.45	0.15	2.47	12.20	3.89	1.14	0.15	3.08	8.26
8	160	200	7.16	1.40	0.30	2.59	11.45	4.19	1.13	0.25	2.90	8.47
10	160	800	7.49	1.13	0.75	3.30	12.67	4.33	1.06	1.10	3.11	9.60
11	1000	1000	8.58	0.84	1.15	3.26	13.83	5.47	0.71	0.95	3.47	10.60
13	----	----	7.02	1.45	0.15	3.20	11.82	3.55	1.09	0.25	3.68	8.57
17	----	1000	8.16	1.18	0.90	2.83	13.07	3.33	0.95	1.20	2.17	7.65

TABLE 8(Cont.). The Milliequivalents of Exchangeable Calcium, Magnesium, Potassium and Hydrogen Found in the Soil from Comparative Farm Plots Receiving Phosphoric Acid and Potash.

	Fertilizer Treatment Total lbs. Per Acre		The Milliequivalents of Exchangeable Cations per 100 Grams of Soil for the Respective Farm Numbers.				
Plot No.	P_2O_5	K_2O	Ca	Mg	K	H	Total m.e.
				Farm No. 9			
7	80	---	2.78	0.60	0.20	1.81	5.39
8	80	100	2.61	0.81	0.20	1.97	5.59
10	80	400	2.58	0.84	0.30	1.76	5.48
11	500	500	2.58	0.35	0.20	1.26	4.39
15	---	---	2.58	0.65	0.20	2.02	5.45
17	---	500	2.33	0.81	0.30	1.23	4.67
				Farm No. 10			
7	80	---	7.15	0.97	0.20	2.12	10.42
8	80	100	7.16	0.93	0.25	2.39	10.73
10	80	400	6.58	0.94	1.10	2.47	11.09
11	500	500	6.83	0.85	0.90	2.50	11.08
15	---	---	7.05	0.91	0.25	1.88	10.09
17	---	500	5.66	0.86	1.00	2.00	9.52
				Farm No. 11			
7	80	---	8.78	1.24	0.15	1.30	11.47
8	80	100	12.43	1.93	0.15	1.78	16.29
10	80	400	10.04	1.55	0.25	1.17	13.01
11	500	500	8.18	1.17	0.20	0.60	10.15
15	---	---	9.16	1.01	0.15	0.63	10.95
17	---	500	7.91	0.93	0.20	0.46	9.50

TABLE 9. The Exchangeable Calcium, Magnesium, Potassium and Hydrogen Found in Soil From Plots Receiving Phosphoric Acid and Potash Expressed in Percent of the Total Exchange Capacity.

Plot No.	Fertilizer Treatment Total lbs. Per Acre. P_2O_5	K_2O	The Percent of the Exchange Complex Occupied by the Various Cations for the Respective Farm Numbers. Ca %	Mg %	K %	H %	Ca %	Mg %	K %	H %
			Farm No. 1-B				Farm No. 2-A			
7	160	---	54.7	11.8	2.0	31.5	67.1	3.7	2.3	26.9
8	160	200	53.9	12.1	4.0	30.0	56.6	8.8	4.2	30.4
10	160	800	48.1	9.6	14.9	27.4	50.1	3.9	10.7	35.3
11	1000	1000	58.7	3.9	6.9	30.5	57.1	1.4	8.8	32.7
13	----	----	53.8	13.2	2.1	30.9	54.5	11.0	2.3	32.2
17	----	1000	42.1	9.0	19.1	29.8	48.0	5.6	17.0	29.4
			Farm No. 3				Farm No. 4			
7	160	----	82.5	4.7	2.2	10.6	69.0	17.7	1.5	11.8
8	160	200	62.5	5.3	5.7	26.5	60.7	16.7	5.7	16.9
10	160	800	46.2	4.7	13.6	35.5	56.0	15.5	12.4	16.1
11	1000	1000	53.5	1.4	10.5	34.6	60.7	8.9	10.0	20.4
13	----	----	63.3	5.5	2.9	28.3	63.2	19.7	3.2	13.9
17	----	1000	50.0	4.9	15.9	29.2	54.8	14.6	13.3	17.3
			Farm No. 5				Farm No. 6-A			
7	160	----	62.4	14.0	2.5	21.1	50.5	3.1	1.5	44.9
8	160	200	58.8	13.6	5.0	22.6	50.7	1.7	2.1	45.5
10	160	800	53.4	10.7	12.3	23.6	42.8	2.0	9.2	46.0
11	1000	1000	58.9	6.3	9.3	25.5	50.6	1.0	8.4	40.0
13	----	----	54.5	13.0	2.5	30.0	49.8	3.2	1.3	45.7
17	----	1000	48.1	9.2	14.7	28.0	42.2	2.3	10.7	44.8
			Farm No. 7				Farm No. 8			
7	160	----	66.6	11.9	1.2	20.3	47.1	13.8	1.8	37.3
8	160	200	62.5	12.2	2.6	22.7	49.5	13.3	3.0	34.2
10	160	800	59.1	8.9	5.9	26.1	45.1	11.0	11.5	32.4
11	1000	1000	62.0	6.1	8.3	23.6	51.6	6.7	9.0	32.7
13	----	----	59.4	12.3	1.3	27.0	41.4	12.7	2.9	43.0
17	----	1000	62.4	9.0	6.9	21.7	43.5	12.4	15.7	28.4

TABLE 9 (Cont.). The Exchangeable Calcium, Magnesium, Potassium and Hydrogen Found in Soil From Plots Receiving Phosphoric Acid and Potash Fertilizer Expressed in Percent of the Total Exchange Capacity.

Plot No.	Fertilizer Treatment Total lbs. Per Acre		The Percent of the Exchange Complex Occupied by the Various Cations for the Respective Farm Numbers.			
	P_2O_5	K_2O	Ca %	Mg %	K %	H %
			Farm No. 9			
7	80	----	51.6	11.1	3.7	44.9
8	80	100	46.7	14.5	3.6	35.2
10	80	400	47.1	15.3	5.5	32.1
11	500	500	58.8	8.0	4.6	28.6
13	----	----	47.3	11.9	3.7	37.1
17	----	500	49.9	17.3	6.4	26.4
			Farm No. 10			
7	80	----	68.4	9.3	1.9	20.4
8	80	100	66.7	8.7	2.3	22.3
10	80	400	59.3	8.5	9.9	22.3
11	500	500	61.6	7.7	8.1	22.6
13	----	----	69.9	9.0	2.5	18.6
17	----	500	59.5	9.0	10.5	21.0
			Farm No. 11			
7	80	----	76.5	10.8	1.3	11.4
8	80	100	76.3	11.8	0.9	11.0
10	80	400	77.2	11.9	1.9	9.0
11	500	500	80.6	11.5	2.0	5.9
13	----	----	83.7	9.2	1.4	5.7
17	----	500	83..3	9.8	2.1	4.8

TABLE 10. The Exchangeable Potassium Expressed in Pounds of K_2O Per Acre and the Percent of the Applied Potash Absorbed by the Exchange Complex of the Soil from Cooperative Farm Plots Receiving Phosphoric Acid and Potash.

Pounds Per Acre* of Exchangeable Potassium Expressed as K_2O and the Percent of the Applied Potash Found in the Exchange Complex.

Plot No.	Fertilizer Treatment Total lbs. Per Acre P_2O_5	K_2O	Exchangeable K_2O	Applied K_2O Absorbed	Exchangeable K_2O	Applied K_2O Absorbed	Exchangeable K_2O	Applied K_2O Absorbed
			lbs.	%	lbs.	%	lbs.	%
			Farm No. 1-B		Farm No. 2-A		Farm No. 3	
7	160	----	141	----	141	----	235	----
8	160	200	283	71	283	71	471	181
10	160	800	1036	112	753	77	1318	135
11	1000	1000	518	38	612	47	1224	99
13	----	----	141	----	141	----	235	----
17	----	1000	1224	108	1036	90	1601	137
			Farm No. 4		Farm No. 5		Farm No. 6-A	
7	160	----	188	----	188	----	94	----
8	160	200	753	188	377	95	141	24
10	160	800	1507	141	989	100	659	71
11	1000	1000	1318	94	895	71	612	52
13	----	----	377	----	188	----	94	----
17	----	1000	1648	127	1224	104	753	66
			Farm No. 7		Farm No. 8		Average **	
7	160	----	141	----	141	----	----	----
8	160	200	283	71	235	0	----	80
10	160	800	706	71	1036	100	----	101
11	1000	1000	1083	94	895	66	----	70
1e	----	----	141	----	235	----	----	----
17	----	1000	847	71	1130	90	----	99
			Farm No. 9		Farm No. 10		Farm No. 11	
7	80	----	188	----	188	----	141	----
8	80	100	188	0	235	0	141	0
10	80	400	283	24	1036	200	235	24
11	500	500	188	0	847	122	188	9
13	----	----	188	----	235	----	141	--
17	----	500	283	19	942	141	188	9

* An Acre depth of 6 2/3 inches of soil is assumed to weigh 2,000,000 pounds.

** This average is for the first eight farms only.

TABLE 11. The Exchangeable Calcium, Magnesium, Potassium and Hydrogen in Soil from the Cooperative Farm Plots Receiving Phosphoric Acid, Potash, Lime and the Minor Element Mixture in 1941.

Fertilizer Treatment Pounds Per Acre			The Milliequivalents of Exchangeable Cations Per 100 Grams of Soil for the Different Plots on the Respective Farms.															
P_2O_5	K_2O	Ground Lime-stone	Plot No.	Exchangeable Ca	Mg	K	H	Plot No.	Exchangeable Ca	Mg	K	H	Plot No.	Exchangeable Ca	Mg	K	H
							Farm No. 6-B										
----	---	----	1	4.35	0.10	0.17	2.42	12	5.86	0.41	0.28	1.12	23	3.94	0.08	0.10	1.28
500	---	----	5	6.94	0.16	0.12	0.76	16	7.51	0.06	0.14	0.98	27	5.78	0.51	0.13	2.50
---	500	----	7	10.82	0.61	0.41	----	18	6.41	0.14	0.39	0.69	29	5.18	0.69	0.64	1.98
100	100	4000	8	10.05	0.55	0.32	----	19	7.60	0.08	0.30	----	30	9.63	0.64	0.16	----
500	500	----	6	6.30	0.08	0.61	0.80	17	5.89	0.08	0.48	2.02	28	5.23	0.37	0.61	2.44
500	500	4000	9	8.81	0.47	0.51	----	20	7.74	0.12	0.44	----	31	9.61	0.26	0.45	----
---	---	----*	11	5.01	0.36	0.17	1.81	22	3.55	0.06	0.12	0.99	33	4.46	0.19	0.11	2.94
							Farm No. 2-B										
100	100	----	1	3.96	0.10	0.17	2.52	11	4.13	0.41	0.21	2.32	21	3.63	0.40	0.24	2.71
100	100	4000	2	6.11	0.56	0.16	1.25	12	6.30	0.66	0.18	0.60	22	7.60	0.66	0.24	0.53
100	500	----	3	3.47	0.07	0.52	2.85	13	3.52	0.38	0.36	3.24	23	4.16	0.48	0.41	3.34
100	500	4000	4	6.47	0.67	0.44	----	14	5.75	0.42	0.35	0.98	24	6.69	0.78	0.48	0.57
500	500	----	7	4.24	0.14	0.42	2.38	17	3.96	0.28	0.35	2.55	27	3.85	0.33	0.66	2.62
500	500	4000	8	3.63	0.24	0.34	2.17	18	5.62	0.54	0.46	1.89	28	3.66	0.38	0.33	2.04
100	100	----*	10	3.52	0.44	0.17	2.57	20	3.85	0.34	0.19	2.51	30	3.41	0.20	0.19	2.64
							Farm No. 13										
100	100	----	1	2.62	0.10	0.24	4.22	11	2.31	0.09	0.33	4.73	21	3.25	0.12	0.23	3.54
100	100	4000	2	3.47	0.38	0.25	2.98	12	3.55	0.08	0.29	3.27	22	4.07	0.19	0.18	2.24
100	500	----	3	3.00	0.09	0.45	4.20	13	1.79	0.07	0.47	5.72	23	3.25	0.10	0.41	3.01
100	500	4000	4	4.68	0.42	0.35	1.19	14	3.22	0.08	0.50	4.52	24	4.93	0.36	0.39	1.12
500	500	----	7	2.81	0.09	0.32	3.01	17	3.03	0.05	0.43	4.65	27	2.48	0.06	0.36	3.24
500	500	4000	8	4.87	0.11	0.49	1.85	18	5.40	0.42	0.44	2.29	28	4.60	0.08	0.57	1.69
100	100	----*	10	2.42	0.14	0.28	4.85	20	2.78	0.10	0.20	3.99	30	2.04	0.07	0.43	5.09

* This treatment received in addition 400 pounds of Minor Element Mixture.

TABLE 11 (Cont.). The Average Amount of Exchangeable Calcium, Magnesium, Potassium and Hydrogen in Soil from the Cooperative Farm Plots Receiving Phosphoric Acid, Potash, Lime and the Minor Element Mixture in 1941.

Fertilizer Treatment Pounds Per Acre			The Milliequivalents of Exchangeable Cations Per 100 Grams of Soil for the Different Plots on the Respective Farms.				
P_2O_5	K_2O	Ground Limestone	Exchangeable Ca	Exchangeable Mg	Exchangeable K	Exchangeable H	Total m.e.
			Farm No. 6-B				
----	----	----	4.72	0.20	0.18	1.61	6.71
500	----	----	6.74	0.24	0.13	1.41	8.52
----	500	----	7.47	0.48	0.48	0.89	9.32
100	100	4000	9.09	0.42	0.26	----	9.77
500	500	----	5.81	0.18	0.57	1.75	8.31
500	500	4000	8.72	0.28	0.47	----	9.47
----	----	----*	4.34	0.20	0.13	1.91	6.58
			Farm No. 2-B				
100	100	----	3.91	0.30	0.21	2.52	6.94
100	100	4000	6.67	0.63	0.19	0.79	8.28
100	500	----	3.72	0.31	0.36	3.14	7.53
100	500	4000	6.30	0.62	0.42	0.52	7.86
500	500	----	4.02	0.25	0.48	2.52	7.27
500	500	4000	4.30	0.39	0.38	2.03	7.10
100	100	----*	3.59	0.33	0.18	2.57	6.67
			Farm No. 13				
100	100	----	2.73	0.10	0.27	4.16	7.26
100	100	4000	3.70	0.22	0.24	2.83	6.99
100	500	----	2.68	0.09	0.44	4.31	7.52
100	500	4000	4.28	0.29	0.41	1.55	6.53
500	500	----	2.77	0.07	0.37	3.63	6.84
500	500	4000	4.96	0.20	0.50	1.94	7.60
100	100	----*	2.41	0.10	0.30	4.64	7.45

* This treatment received in addition 400 pounds of Minor Element Mixture.

TABLE 12. The Percent of the Exchange Complex Occupied by the Average Amounts of the Exchangeable Cations, and the Exchangeable Potassium Expressed in Pounds of K_2O Per Acre in the Soil, from the Cooperative Farm Plots Receiving Phosphoric Acid, Potash and the Minor Element Mixture in 1941.

Fertilizer Treatment Pounds Per Acre			The Percent of the Exchange Complex Occupied by the Various Cations, and the Exchangeable Potassium Expressed in Pounds of K_2O per Acre** for the Various Farm Numbers.				
P_2O_5	K_2O	Ground Limestone	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	Exchangeable Hydrogen	Exchangeable K_2O
			%	%	%	%	lbs.
			Farm No. 6-B				
——	——	——	70.3	3.0	2.7	24.0	170
500	——	——	79.1	2.8	1.5	16.6	122
——	500	——	80.2	5.2	5.2	9.4	452
100	100	4000	93.0	4.3	2.7	——	245
500	500	——	69.9	2.2	6.9	23.1	537
500	500	4000	92.1	3.0	4.9	——	443
——	——	——*	66.0	3.0	2.0	29.0	122
			Farm No. 2-B				
100	100	——	56.3	4.3	3.0	36.4	198
100	100	4000	80.6	7.6	2.3	9.5	179
100	500	——	49.4	4.1	4.8	41.7	339
100	500	4000	80.2	7.9	5.3	6.6	396
500	500	——	55.2	3.4	6.6	34.8	452
500-	500	4000	60.6	5.5	5.4	28.5	358
100	100	——*	53.8	5.0	2.6	38.6	170
			Farm No. 13				
100	100	——	37.6	1.4	3.7	57.3	254
100	100	4000	52.9	3.1	3.4	40.6	226
100	500	——	35.6	1.2	5.9	57.3	414
100	500	4000	65.5	4.4	6.3	23.8	386
500	500	——	40.5	1.0	5.4	53.1	348
500	500	4000	65.3	2.6	6.6	25.5	471
100	100	——*	32.3	1.3	4.0	62.4	283

* This treatment will receive in addition 400 pounds of Minor Element Mixture

** An Acre Depth of 6 2/3 inches of soil is assumed to weigh 2,000,000.

TABLE 13. The Available Ions by Rapid Soil Tests and the pH Value of Soils from Cooperative Plots Receiving Treatments of Phosphoric Acid and Potash.

	Fertilizer Treatment Pounds Per Acre		Available Ions by Rapid Soil Tests									
Plot No.	P_2O_5	K_2O	Ca	Mg	Al	Fe	NO_3	NH_4	P	K	Mn	pH Value
					Farm No. 1-B							
7	160	——	H	M	T	T	T	T	T	T	M	5.9
8	160	200	H	M	T	T	T	T	T	L	L	5.9
10	160	800	L	L	T	-	T	T	T	X	L	5.9
11	1000	1000	X	L	T	-	T	T	H	X	L	5.5
13	——	——	M	M	T	T	T	T	-	T	L	6.0
17	——	1000	T	L	L	T	T	T	-	X	L	5.9
					Farm No. 2-A							
7	160	——	H	M	T	-	-	-	L	T	L	6.2
8	160	200	H	M	T	-	-	-	T	M	L	6.0
10	160	800	L	M	T	-	T	-	T	X	L	6.1
11	1000	1000	H	M	T	-	-	-	H	X	L	5.9
13	——	——	L	M	T	-	-	-	-	T	L	6.0
17	——	1000	T	M	T	-	-	-	-	X	L	6.3
					Farm No. 3							
7	160	——	X	M	-	-	T	-	L	T	M	6.4
8	160	200	X	M	-	-	T	T	L	H	M	6.2
10	160	800	H	M	T	-	L	T	L	XX	M	6.0
11	1000	1000	X	M	T	-	T	-	H	XX	M	5.7
13	——	——	H	M	T	-	T	-	-	T	M	6.0
17	——	1000	H	L	T	-	T	-	T	XX	M	6.1
					Farm No. 4							
7	160	——	XX	X	T	-	T	T	T	M	M	6.4
8	160	200	XX	X	T	-	L	T	T	X	M	6.3
10	160	800	X	X	T	-	L	T	T	XX	M	6.5
11	100	1000	XX	M	-	-	M	T	M	XX	M	6.4
15	——	——	XX	X	T	-	T	T	T	M	M	6.6
17	——	1000	X	X	-	-	T	T	T	XX	M	6.7
					Farm No. 5							
7	160	——	X	H	T	-	-	-	T	T	M	6.1
8	160	200	X	H	T	-	T	-	T	M	M	6.1
10	160	800	H	M	T	-	T	-	L	X	M	6.3
11	1000	1000	X	M	-	-	T	-	H	X	M	6.2
13	——	——	M	H	L	-	-	-	T	T	L	5.6
17	——	1000	M	M	T	-	T	-	-	X	M	6.0
					Farm No. 6-A							
7	160	——	L	L	T	-	-	-	T	-	M	5.6
8	160	200	L	L	L	-	T	T	T	T	M	5.6
10	160	800	L	L	T	-	L	T	T	H	M	5.6
11	1000	1000	M	L	T	-	-	-	L	X	M	5.5
13	——	——	L	L	L	-	-	-	-	-	M	5.7
17	——	1000	T	L	L	-	T	-	-	X	M	5.7

TABLE 13 (Cont.). The Available Ions by Rapid Soil Tests and the pH Value of Soils from Cooperative Farm Plots Receiving Treatments of Phosphoric Acid and Potash.

Plot No.	Fertilizer Treatment Pounds Per Acre: P_2O_5	K_2O	Available Ions by Rapid Soil Tests: Ca	Mg	Al	Fe	NO_3	NH_4	P	K	Mn	pH Value
					Farm No. 7							
7	160	———	XX	H	T	-	M	T	T	T	M	6.4
8	160	200	XX	H	T	-	M	T	T	L	M	6.4
10	160	800	XX	M	L	-	M	-	T	H	M	6.2
11	1000	1000	XX	M	T	-	L	T	L	X	M	6.2
13	———	———	XX	H	T	-	M	T	T	T	M	6.4
17	———	1000	XX	M	T	-	M	T	T	X	M	6.4
					Farm No. 8							
7	160	———	M	H	T	-	L	-	T	T	M	5.8
8	160	200	M	H	T	-	T	T	L	L	M	6.0
10	160	800	L	M	T	-	T	T	T	X	M	5.9
11	1000	1000	X	M	-	-	M	T	H	X	M	5.7
13	———	———	L	H	T	-	M	T	-	T	M	5.7
17	———	1000	T	M	T	-	-	-	T	X	M	6.1
					Farm No. 9							
7	80	———	T	M	M	L	M	T	L	L	T	5.3
8	80	100	T	M	M	L	L	L	T	L	T	5.3
10	80	400	T	M	L	T	M	T	L	M	T	5.2
11	500	500	T	L	L	-	M	T	H	M	T	5.3
13	———	———	T	L	M	M	H	L	L	M	T	5.2
17	———	500	T	M	T	T	L	T	M	M	T	5.4
					Farm No. 10							
7	80	———	XX	H	T	-	T	-	T	T	M	6.3
8	80	100	XX	H	T	-	T	-	T	T	L	6.3
10	80	400	X	M	T	-	L	T	L	X	M	6.3
11	500	500	X	M	-	-	M	T	H	X	M	6.3
13	———	———	XX	M	T	-	T	T	T	T	M	6.6
17	———	500	X	M	T	-	T	T	-	X	M	6.5
					Farm No. 11							
7	80	———	XX	H	-	-	T	-	T	T	M	6.7
8	80	100	XX	X	T	-	L	-	M	T	L	6.7
10	80	400	XX	X	T	-	L	-	T	T	L	6.8
11	500	500	XX	X	-	-	L	-	L	T	L	6.7
13	———	———	XX	X	-	-	L	-	T	T	L	6.9
17	———	500	XX	H	-	-	L	-	T	T	L	6.9

TABLE 14. The Available Ions by Rapid Soil Tests and the pH Value of Soils from Cooperative Farm Plots receiving Phosphoric Acid, Potash, Lime and a Minor Element Mixture, in 1941.

Plot No.	Fertilizer Treatment Pounds Per Acre: P_2O_5	K_2O	Ground Limestone	Available Ions in Soil Samples from Farm No. 6-B: Ca	Mg	Al	Fe	NO_3	NH_4	P	K	Mn	pH Value
1				M	M	L	T	L	T	T	T	T	5.7
12	---	---	----	H	M	T	T	T	T	T	T	T	6.5
23				L	M	T	T	T	T	-	T	T	6.2
Ave.				M	M	T	T	T	T	T	T	T	6.1
5				H	M	T	T	L	T	T	-	T	6.4
16	500	---	----	X	M	T	T	T	T	L	T	T	6.3
27				H	M	M	T	T	T	T	T	T	5.8
Ave.				H	M	L	T	T	T	T	T	T	6.2
7				X	H	T	T	L	L	T	L	T	7.3
18	---	500	---	H	M	T	T	T	T	T	L	T	6.5
29				H	M	M	T	L	T	T	H	T	5.8
Ave.				H	M	L	T	L	T	T	M	T	6.5
8				X	H	T	T	T	L	T	T	T	7.3
19	100	100	4000	X	M	T	T	L	T	T	T	T	6.8
30				X	M	T	T	T	T	T	T	T	6.8
Ave.				X	M	T	T	T	T	T	T	T	7.0
6				H	M	T	T	L	T	L	M	T	6.8
17	500	500	----	H	M	T	T	T	T	L	M	T	6.4
28				H	M	M	T	L	T	T	H	T	5.6
Ave.				H	M	L	T	L	T	L	M	T	6.3
9				X	H	T	T	L	T	T	L	T	7.1
20	500	500	4000	X	M	T	T	L	T	L	L	T	6.8
31				X	M	T	T	T	T	T	M	T	7.0
Ave.				X	M	T	T	L	T	T	L	T	7.0
11				M	M	T	T	T	T	T	T	T	6.5
22	---	---	----*	L	M	T	T	L	T	-	T	T	6.8
33				L	M	L	T	T	T	T	T	T	6.4
Ave.				L	M	T	T	T	T	T	T	T	6.8

* This treatment received in addition 400 pounds of the Minor Element Mixture.

TABLE 14 (Cont.). The Available Ions by Rapid Soil Tests and the pH Value of Soils from Cooperative Farm Plots Receiving Phosphoric Acid, Potash, Lime and a Minor Element Mixture in 1941.

	Fertilizer Treatment Pounds Per Acre			Available Ions in Soil Samples from Farm No. 2-B									
Plot No.	P_2O_5	K_2O	Ground Limestone	Ca	Mg	Al	Fe	NO_3	NH_4	P	K	Mn	pH Value
1				L	M	L	T	T	T	T	T	L	5.6
11				M	M	L	T	T	L	T	T	L	5.8
21	100	100	----	L	L	L	T	L	L	T	L	L	5.6
Ave.				L	M	L	T	T	L	T	T	L	5.7
2				M	M	T	T	T	T	T	T	T	6.2
12				H	M	T	T	L	T	T	T	+	6.3
22	100	100	4000	X	M	T	T	M	L	T	L	T	6.4
Ave.				H	M	T	T	L	T	T	T	T	6.3
3				L	M	L	T	T	T	T	L	M	5.5
13				L	M	L	T	T	L	T	L	L	5.4
23	100	500	----	L	L	L	T	L	L	T	M	L	5.6
Ave.				L	M	L	T	T	L	T	L	L	5.5
4				M	M	T	T	T	-	T	M	+	6.6
14				H	M	T	T	T	L	T	L	L	6.4
24	100	500	4000	M	M	T	T	M	T	T	M	T	6.5
Ave.				M	M	T	T	L	T	T	M	T	6.5
7				L	M	T	T	L	T	T	M	T	5.6
17				M	M	L	T	T	L	T	L	L	5.6
27	500	500	----	M	L	L	T	M	L	T	X	T	5.5
Ave.				M	M	L	T	L	L	T	M	T	5.6
8				L	M	T	T	L	-	T	L	T	5.7
18				H	M	T	T	M	T	L	M	L	6.0
28	500	500	4000	L	M	T	T	L	T	T	M	+	5.9
Ave.				M	M	T	T	L	T	T	M	T	5.9
10				L	M	L	T	L	-	T	T	T	5.5
20				M	M	L	T	M	L	L	L	L	5.6
30	100	100	----*	L	L	M	T	L	L	-	L	T	5.5
Ave.				L	M	L	T	L	T	T	L	T	5.5

* This treatment received in addition 400 pounds of the Minor Element Mixture.

TABLE 14 (Cont.). The Available Ions by Rapid Soil Tests and the pH Value of Soils from Cooperative Farm Plots Receiving Phosphoric Acid, Potash, Lime and a Minor Element Mixture in 1941.

	Fertilizer Treatment Pounds Per Acre			Available Ions in Soil Samples from Farm No. 13									
Plot No.	P_2O_5	K_2O	Ground Limestone	Ca	Mg	Al	Fe	NO_3	NH_4	P	K	Mn	pH Value
1				T	T	H	L	L	M	-	L	T	4.8
11	100	100	----	T	T	H	L	L	M	T	L	T	4.7
21				L	L	M	L	T	L	T	T	T	4.9
Ave.				T	T	H	L	L	M	T	L	T	4.8
2				L	L	H	T	M	T	-	T	+	5.0
12	100	100	4000	L	L	H	L	T	M	T	L	T	5.1
22				M	L	L	T	L	M	T	T	T	5.4
Ave.				L	L	M	T	L	L	T	T	T	5.2
3				L	T	H	L	M	L	-	M	T	4.8
13	100	500	----	T	T	H	L	T	M	-	M	T	4.8
23				L	L	L	T	L	M	T	M	L	5.1
Ave.				L	T	M	L	L	M	+	M	T	4.9
4				L	M	L	T	M	T	T	L	T	5.6
14	100	500	4000	L	L	H	T	L	M	T	M	T	5.0
24				M	M	T	T	M	L	T	L	+	5.6
Ave.				L	M	L	T	M	L	T	L	T	5.4
7				T	T	H	T	L	L	L	L	T	5.0
17	500	500	----	L	L	H	T	L	L	T	M	T	4.9
27				T	T	H	T	M	L	T	L	T	4.9
Ave.				T	T	H	T	L	L	T	L	T	4.9
8				M	L	M	T	L	M	T	M	T	5.6
18	500	500	4000	H	M	L	T	L	M	T	M	T	5.3
28				M	M	M	T	M	T	L	M	+	5.4
Ave.				M	M	M	T	L	L	T	M	T	5.4
10				T	L	H	L	T	M	T	L	L	5.0
20	100	100	----*	T	T	H	L	T	L	-	T	T	4.7
30				T	T	H	L	T	M	T	L	L	4.7
Ave.				T	T	H	L	T	M	T	L	T	4.8

* This treatment received in addition 400 pounds of the Minor Element Mixture.

SUMMARY

The response of crops to various applications of potash, superphosphate, lime and a minor element mixture was observed on some representative soil series of the state. Soil samples from some of these treatments were taken into the laboratory to study the availability of potassium as it was affected by the addition of other elements. The samples were analyzed for exchangeable calcium, magnesium, potassium and hydrogen. The rapid soil tests as employed at Maryland (21) were used to determine the available potassium and other elements held by the sorption complex of these soils.

The results of this study suggest the following general conclusions:

1. A sufficient supply of all the required nutrients is an essential factor in crop production. The influence, therefore, of a single element in fertilizing field crops is difficult to measure.

2. Superphosphate applied with potash fertilizer decreases the amount of potassium held in the exchangeable form. This effect is most noticeable in the Sassafras and Manor soil series.

3. A large portion of the exchangeable magnesium is displaced from the exchange complex of soils as a result of heavy potash and phosphorus fertilization. Magnesium amendments are therefore necessary to compensate for this loss.

4. Treatments of superphosphate and lime on soils low in exchangeable hydrogen also decreases the amount of applied potassium retained in the exchangeable form.

In general, it is conclusive that a sufficient supply of available plant food is an important factor in maintaining a fertile soil. This supply includes all the elements used by plants, and when deficient elements are noted by soil tests, they should be supplied in amounts that will result in a sufficiency of all the available nutrients for use in crop growth.

BIBLIOGRAPHY

1. Allaway, H. and Pierre, W. H. Availability, Fixation and Liberation of Potassium in High-lime Soils. Jour. Am. Soc. Agron. 31: 940-43. November 1939.

2. Bartholomew, R. P. and Janssen, G. The Rate of Absorption of Potassium by Plants and Its Possible Effect Upon the Amount of Potassium Remaining in Soils From Application of Potassium Fertilizers. Ark. Agr. Exp. Sta. Bul. 265. 1931.

3. Blume, J. M. and Purvis, E. R. Fixation and Release of Applied Potash on Three Coastal Plain Soils. Jour. Am. Soc. Agron. 31: 857-68. October 1939.

4. Bray, R. H. and DeTurk, E. E. The Release of Potassium from Non-replaceable Forms in Illinois Soils. Proc. Soil Sci. Soc. of Am. 3: 101-106. 1938.

5. Chaminade, R. and Drouneau, G. Recherches sur la Chimique des Cations Exchangeables. Am. Agron. 6: 677-691. 1936

6. Enfield, G. H. and Conner, S. D. Fixation of Potash by Muck Soils. Jour. Am. Soc. Agron. 28: 146-55. February 1936.

7. Fine, L. O., Bailey, T. A. and Emil Truog. Availability of Fixed Potassium as Influenced by Freezing and Thawing. Proc. Soil Sci. Soc. of Am. 5: 183. 1940.

8. Gammon, N. A Base Exchange Study on Some Maryland Soils. Master's Thesis at the University of Maryland (unpublished data).

9. Gorbunov, N. I. The Nature of Potassium Fixation in Non-exchangeable Form. Kimiztziya Sotzialist, Zenledeliya. No. 2-3: 82-92. 1936.

10. Harris, H. C. Effect of Lime on the Availability and Fixation of Potash in Soils. Soil Sci. 44: 265-275. 1937.

11. Hester, J. B. and Shelton, F. A. Availability of Replaceable Potassium to Tomatoes on a Sassafras Sandy Loam. Jour. Am. Soc. Agron. 32: 563-569. August 1940.

12. Hoagland, D. R. and Martin, J. C. Absorption of Potassium by Plants in Relation to Replaceable, Non-replaceable and Soil Solution Potassium. Soil Sci. 36: 1-33. 1933.

13. Jenny, H. and Shade, E. R. The Potassium-Lime Problem in Soils. Jour. Am. Soc. Agron. 26: 162-170. 1934.

14. Joffe, J. S. and Kolodny, L. Fixation of Potassium in Soils. Proc. Soil Sci. Soc. of Am. 1 (1936): 187-92. 1937.

15. Joffe, J. S. and Kolodny, L. The Effect of Alternate Drying and Wetting on the Base Exchange Complex with Special Reference to the Behavior of the Potassium Ion. Proc. Soil Sci. Soc. of Am. 3: 107-111. 1938.

16. Joffe, J. S. and Levene, A. K. The Relation of Potassium Fixation to the Exchange Capacity of Soils. Proc. Soil Sci. Soc. of Am. 4: 157-161. 1939.

17. MacIntire, W. H. The Liberation of Native Soil Potassium Induced by Different Calcic and Magnesic Materials as Measured by Lysimeter Leachings. Soil Sci. 8: 337-396. 1919.

18. Page, J. B. and Baver, L. D. Ionic Size in Relation to Fixation of Cations by Colloidal Clay. Proc. Soil Sci. Soc. of Am. 4: 150-155. 1939.

19. Schueler, J. E. and Thomas, R. P. Determination of Potassium by Sodium Cobaltinitrite. Ind. and Eng. Chem. Anal. Edi. 5: 163-165. May 1933.

20. Shaw, W. M. and MacIntire, W. H. Relationship Between Water-Soluble, Replaceable and Fixed Fractions of Potash Additions to Soils. Proc. Soil Sci. Soc. of Am. 1 (1936): 143-8. 1937.

21. Thomas, R. P. and Schueler, J. E. Potassium Retained in the Exchangeable Form by Some Maryland Soils. Jour. Am. Soc. Agron. 29: 17-22. January 1937.

22. Thomas, R. P. and Williams, R. C. A Comparison of the Results of Rapid Tests with the Amounts of Available Nutrients Obtained by Quantitative Methods on Maryland Soils. Proc. Soil Sci. Soc. of Am. 1 (1936): 243-254. 1937.

23. Truog, E. and Jones, R. J. Fate of Soluble Potash Applied to Soils. Ind. Eng. Chem. 30: 882-885. 1938.

24. Volk, G. W. The Nature of Potash Fixation in Soils. Soil Sci. 45: 263-276. 1938.

25. Volk, N. J. Fixation of Potash in Difficultly Available Form in Soils. Soil Sci. 37: 267-87. 1934.

26. Wood, L. K. and DeTurk, E. E. Absorption of Potassium in Soils in Non-Replaceable Forms. Proc. Soil Sci. Soc. of Am. 5: 152-161. 1940.