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CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE
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RALEIGH AND WEST RALEIGH

DIVISION OF AGRONOMY

RELATION OF THE MINERALOGICAL AND CHEMICAL COMPOSITION TO THE FERTILIZER REQUIREMENTS OF NORTH CAROLINA SOILS

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[1]In coöperation with the U. S. Department of Agriculture, Bureau of Plant Industry.
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[4]In coöperation with the U. S. Department of Agriculture, Office of Experiment Stations.

RELATION OF THE MINERALOGICAL AND CHEMICAL COMPOSITION TO THE FERTILIZER REQUIREMENTS OF NORTH CAROLINA SOILS

By J. K. Plummer, Soil Chemist

In the systematic study of soils little attention has been given in the past to the minerals which comprise the greater part of most soils. Since the time of Liebig, investigators have devoted their attention toward determining the amounts of the various elements of plant food, giving little thought to the way these elements were held in the soil.

Much time has been spent in field experimentation and in a study of the physical properties of soils; and more recently the biological side has occupied the attention of many investigators. The results of these different methods of attack have thrown much light on the important problem of producing maximum crops at the minimum cost.

It would appear that a knowledge of the amounts of the various plant food constituents of the soil, from which the plant must draw its nourishment, and the form in which these elements are held would be of the highest importance to the intelligent cultivator of the soil. Taking this information with that afforded by carefully conducted field tests, much light will be thrown on the problem of soil fertility.

This bulletin has been prepared with the end in view of supplying additional information to that which has already been secured as to the nature of the soils of North Carolina. These facts will be helpful in forming a more correct judgment with reference to the future management and treatment in building up a rational system of agriculture in the State.

In the laboratory determinations of the more important elements of plant food have been made on over 1,600 samples of soil in connection with the soil survey of the State. Field experiments of the Division have been running twelve years on soils representing the important types of the three large provinces into which the State has been divided, namely, Mountain, Piedmont, and Coastal Plain. Mineralogical analyses have been made on the sand and silt separates on some three hundred soils by use of the methods described by McCaughey and Fry.[1]

The value of the mineralogical analyses cannot be overestimated, as they reveal the elements as they are found in the soil. These analyses supplement the total determinations by chemical methods. By the chemical analyses the total amounts of the different plant food constituents are obtained, but little information is gained as to the form in which this reserve is stored in the soil, whereas, the mineralogical analyses is mainly concerned in showing the chief forms of combinations in which the potential plant food occurs. With the mineralogical analyses an approximation as to the amount of each plant food constituent may be obtained. Their value lies in showing the form in which the plant food constituents are held. Experience has taught that the arbitrarily chosen solvents for measuring the more available portion of the stored plant food have given conflicting results as to the actual fertilizer deficiencies

[1]Bulletin No. 91, Bureau of Soils, U. S. Department of Agriculture.

of soils. By knowing the minerals that carry this stored plant food and the reaction of these minerals toward solution, certainly a more intelligent opinion may be rendered as to the possible requirements of soils for the various fertilizing materials.

Description of Minerals Carrying Plant Food in North Carolina Soils.

Potash, the felspars, orthoclase and microcline, and the micas (muscovite and biotite) are the minerals which supply the soils of this State with potash. These minerals are widely distributed and occur in nearly all the soils examined to a greater or less extent. However, there is wide variation in the amounts of these minerals found in the different provinces of the State. In many of the Mountain soils potash is derived principally from the micas, muscovite and biotite furnishing by far the greater part of the potash found in soils of this section of the State. In the Piedmont section, the micas have been replaced to some extent by the felspars, but in many of the soils of this region, the former minerals furnish much of their potash supply. Orthoclase and microcline are the predominant potash-bearing minerals of the Coastal Plain, the micas occurring only as traces in many of these soils.

Often orthoclase fragments assume a fibrous appearance and are rounded in contour, as though they had been weathered to some extent. Microcline always shows well preserved faces and sharp edges, apparently having been very little affected by natural agencies, which are constantly operating in the soil. Biotite or black mica readily forms alteration products, passing over into chlorite and epidote. In this mineral the potash is held in the more available form than in any other mineral found in our soils. It contains considerable oxide of iron, which is very likely responsible for the readiness with which this mineral is decomposed. Muscovite, from its optical properties, appears to weather little or none, but there is evidence that this mineral does give up its potash with greater readiness than do the felspars.

Results by Other Investigators With Potash Minerals.

E. Blanck[2] gives results of comparative tests in pot experiments with various silicates as the source of potash. He finds that the micas furnish a more available supply of this constituent than do the felspars.

D. N. Praenishnikov[3] found that in comparing the potash silicates as the source of potash for plants, biotite and muscovite were superior to the felspars as carriers of potash.

Fraps[4] reports that all the potash is extracted from biotic with strong HCL, about one-third from muscovite, and only a small percentage from orthoclase and microcline. He states that practically no potash is removed from orthoclase and microcline by one-fifth normal nitric acid, less than 10 per cent. from biotite, and 15 per cent. from muscovite.

These conclusions are borne out in our field experiments, which will be discussed more in detail in the following pages.

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[2] Jour. Landw. 61, 1913, No. 1, pp 1-10.
[3] Landw. Ves. Stat. 77, 1912, pp 399-411.
[4] Tex. Station Bulletin 145.

Lime.

The lime bearing minerals are epidote, hornblende, garnet, and the plagioclase or lime-soda felspars. Calcite so valuable for its content of calcium carbonate, has been found in but one instance. This was in a soil which had a marl bed three feet beneath the surface. Epidote has been found present in all the soils examined. This is a metamorphic mineral, and its wide distribution can be accounted for by its mode of formation, being one of the final products from the alteration of the more easily decomposable minerals augite, hornblende, and micas. It occurs as thick fragments, showing little signs of having undergone chemical decomposition.

It is epidote that furnishes the greater part of lime for many of the soils examined. Hornblende alters to chlorite and epidote, giving up some of its lime in the process of alteration. This mineral furnishes lime in a more easily accessible state for use by the plant than any except the felspars. It often occurs in fragments in which one end of the crystal shows alteration to epidote and the other part remains as hornblende. Garnet has not been found as commonly as has epidote and hornblende. It occurs in thick grains, often rounded in contour. The plagioclase felspars have been found in many of the soils of all three provinces of the State, however, they are most abundantly encountered in the Mountain and Piedmont Sections. In none of the soils do these minerals exist to a great extent, probably due to the ease with which they are decomposed; supposedly giving up their lime in the form of carbonate. It is in the form of the felspars that lime under natural conditions is most available to plants in North Carolina soils. Also these minerals furnish much of the soda which may replace or drive out potash from its state of combination in the finer particles of soils. Augite has been found in some of the soils and is quite common in those of the Iredell series.

Another alteration product of hornblende, the principal decomposition product of biotite, is chlorite, an aluminum, magnesium silicate. It is in chlorite that much of the magnesium is held in North Carolina soils, especially those of the Coastal Plain section.

Phosphoric Acid.

Apatite is the only mineral found in North Carolina soils which carries phosphoric acid to any extent. In very few instances has this mineral been found in the soils of the Coastal Plain. This is in accord with the total chemical analyses. The soils of the Piedmont and Mountain sections contain apatite to a much larger extent, but here the amount is only a trace. More often than otherwise, this mineral is found included in quartz and other minerals; in this form it is doubtful if the plant can draw much of its phosphoric acid from this source. Compared to potash, lime, and magnesia bearing minerals, apatite occurs as mere traces in our soils.

Rutile, zircon, toumaline, sillimanite are common minerals of these soils, but as these have little or no plant food value, a description of them will not be given here.

Magnetite, an oxide of iron, is a common mineral of our soils, and is of value in furnishing iron to plants.

Quartz is by far the most predominant mineral existing in most of the soils of North Carolina, the only exception being those of the Iredell Series. In this series quartz is subordinate to epidote and hornblende. Much information can be obtained by a close observation of the quartz fragments as to the conditions through which a soil has passed. These fragments are often rounded, showing that erosion has taken place and that they have been subjected to great leaching. Especially is this true of the soils of the Coastal Plain.

In many of the Coastal Plain soils, especially those of the Portsmouth series, an abundance of animal remains, phytolitharien, sponge spicules, or rhizopoda casts are found. The presence of these animal remains indicate that at some previous time these soils were covered with water. This may be responsible for the low state of productivity of these soils.

Invariably the silt separates contain a larger amount of plant food bearing minerals than do the sands, and in the Piedmont and Mountain sections these minerals have suffered greater decomposition than those in the sands. Often the silt separates from the Coastal Plain soils present pure clean faces, as though little alteration had taken place.

As quartz is the most abundant mineral found in these soils, and as it has no plant food value so far as is known, in the mineralogical examinations, the author has done as McCaughey and Fry did; compared the other minerals to quartz, and knowing no better way to show the mineralogical composition, have tabulated these analyses after their fashion.

Mountain Soils.

Classification.—The soils of the Mountain section are somewhat analagous to those of the Piedmont Plateau, but in all cases they have been considered as belonging to separate series. All the upland soils encountered so far in the detail soil survey have been considered as belonging to the one broad series known as Porter's. The various types of this series have been formed from schists, gniesses, and granites. The individual types are more dissimilar, perhaps, than is commonly the case, but it has not seemed possible to form a new series in any of the areas so far surveyed. With the extension of the survey to other counties, it is possible that representative types of other soil series will be formed. There is little doubt, however, that the great bulk of the upland falls within the present limits of the Porter's series. The two extensive upland soils are loam and sandy loam, while three other types are represented by smaller areas. These are the clay, sand, and black loam.

The valley and bottom land soils are included in the Toxaway series. These are of alluvial origin, modified by colluvial wash, and have been formed from washing of the Porter's series, and deposited by streams. The surface of these soils is flat, or level, with a gradual slope toward the streams. They lie at sufficient elevations above the normal water level of the streams so as to be fairly easily drained. However, most of these soils are subject to frequent overflow. The two types thus far found are the Toxaway loam and Toxaway fine sandy loam.

Location of Experimental Fields.

Field experiments are being conducted on four of the more important of these mountain soils. The data therefore secured and published can be applied to practically all of this section.

The mountain work is located at the following places:

1. The Buncombe Test Farm, about midway between Black Mountain and Swannanoa in Buncombe County. This is one of six test fields owned and operated by the State Department of Agriculture.

2. The Hendersonville field, one mile northeast of the railroad station at Hendersonville, Henderson County, on the farm of B. W. Marshall.

3. The Blantyre field, one mile northeast of Blantyre, on the farm of Charles Baldwin. These last two fields are in easy walking distance from stations of Hendersonville and Black Mountain or Swannanoa.

Results on the Blantyre Field.[5]

The Blantyre Field is typical Porter's clay, and is representative of much of the heavy upland soils of the mountains. It consists of twelve one-twentieth acre plats. This field was established in the spring of 1910. Corn was grown on all the plats, it being the first crop of the following three-year rotation.

First Year.—Corn.
Second Year.—Wheat.
Third Year.—Red clover.

The following materials were used as carriers of the different elements of plant food:

Dried blood for nitrogen.
Acid phosphate for phosphoric acid.
Potassium sulphate for potash.
Rock lime for lime.

The rate of application is based on the amount of the various plant foods known to be removed by maximum crops. In the case of corn 100 bushels was taken as a maximum yield. This may seem high to some, but many such yields are yearly obtained in the State and over twice this amount has been produced on a measured acre. Even on this very much depleted field, we obtained a yield of nearly sixty bushels by the use of commercial fertilizers alone. In order to secure the required amount of plant food it was necessary to apply the following amounts of materials:

Dried Blood.—1,062 lbs.

Acid Phosphate.—350 lbs.

Sulphate of Potash.—170 lbs.

Lime was applied at the rate of 1,000 pounds of rock lime per acre.

The following table gives the treatment and the yield of each of the plats:

5 See N. C. Dept. Agr. Bul., Vol. 32, No. 5, for details of field results for Mountain Section used his Bulletin.

TABLE 1. RESULTS ON PORTER'S CLAY. CHAS. BALDWIN'S FARM, BLANTYRE, TRANSYLVANIA CO., N. C.

Plat No.	TREATMENT	Yield per Acre		Increase	
		Grain, Bushels	Stover, Pounds	Grain, Bushels	Stover, Pounds
1	None	23.1	1590	----------	----------
2	Lime (CaO)	28.4	2030	5.3	440
3	Nitrogen	26.7	2020	3.6	430
4	Phosphoric Acid	39.0	2200	15.1	860
5	Potash	19.7	1180	—4.2	—160
6	None	23.9	1340	----------	----------
7	Nitrogen, Phosphoric Acid	55.0	3360	31.1	2020
8	Nitrogen, Potash	28.7	2810	4.9	1470
9	Phosphoric Acid, Potash	40.1	2130	15.7	780
10	Nitrogen, Phosphoric Acid, Potash	52.7	3240	28.3	1870
11	None	24.4	1370	----------	----------
12	Lime, Nitrogen, Phosphoric Acid, Potash	59.8	3850	35.4	2480
	Average gain for Nitrogen			10.3	1128
	Average gain for Phosphoric Acid			22.0	895
	Average gain for Potash			—.85	110
	Average gain for Lime (CaO)			6.2	525

These results certainly indicate that phosphoric acid is needed first on this soil. Acid phosphate alone gave an increase of over fifteen bushels per acre. Nitrogen alone gave an increase of only 3.57 bushels, but when applied in addition to phosphoric acid it gave an increase of sixteen bushels, nearly one bushel more than did phosphoric acid over no fertilizer. Potash alone gave a smaller yield than no fertilizer, very little increase when applied in addition to nitrogen or phosphoric acid separately, and a decrease in the addition of these together.

TABLE 2.—CHEMICAL AND MINERALOGICAL COMPOSITION OF

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2-3 inches----2,000,000 lbs Subsoil, 28 inches-------8,000,000 lbs				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil	*Inches*					*Percent.*	*Percent.*	
1187	0-8	1,055	618	12,312	1,419	29	33	Biotite, muscovite, orthoclase.
Subsoil								
1188	10-36	2,012	8,742	102,182	7,562	27	36	Biotite, orthoclase, muscovite, epidote.

Lime gives fair increase, either alone or in addition to a complete fertilizer, the gain over no fertilizer being at the rate of 5.3 bushels, and in addition to all these elements at the rate of 7.1 bushels, making an average of 6.2 bushels per acre. This would indicate that lime could be used at a profit on this soil.

While it is not safe to draw definite conclusions from one season's work, the marked benefit of phosphoric acid and nitrogen certainly justifies the assumption that the phosphoric acid and nitrogen supply must be increased in order to produce large crops permanently.

A study of Table No. 2 will certainly aid in the interpretations of the results obtained from this field.

The surface 6⅔ inches of this soil contains enough potash for nearly 375 one-hundred bushel corn crops. This potash is principally in the form of biotite and muscovite, there is some orthoclase in the sand particles, but the silt is mainly micas. Twenty-five such crops would, if all the phosphoric acid was available, require an amount of phosphoric acid equal to the total amount existing in the surface 6⅔ inches. The mineralogical analysis shows that much of this phosphoric acid is in the form of inclusions in quartz, and that it is exceedingly doubtful if the plant can obtain this phosphoric acid at all. The nitrogen supply for one-hundred bushel crops is limited to about twelve years. Lime in this soil is principally in the form epidote, there is, however, some hornblende present.

Results on the Hendersonville Field.

The Hendersonville Field is located on typical Porter's sandy loam and is exceptionally uniform throughout. There are eleven plats in this field, the nine fertilized ones receiving the same treatment as the corresponding ones on the Blantyre Field. This field, too, was established in the spring of 1910, and corn was grown the first year.

PORTER'S CLAY, BLANTYRE, HENDERSON COUNTY.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite,	Epidote, hornblende, zircon, rutile, microcline, apatite, as inclusions in quartz	Epidote, chlorite hornblende, rutile, zircon, magnetite, microcline	Biotite is altered and fresh. Orthoclase is fresh. Some secondary quartz.
Biotite, muscovite, orthoclase	Chlorite, hornblende, rutile, zircon	Chlorite, hornblende, rutile, zircon, microcline, magnetite	Biotite badly altered. Orthoclase shows signs of weathering.

The following table gives the treatment and yields of corn in 1910:

TABLE 3. RESULTS ON PORTER'S SANDY LOAM. B. W. MARSHALL'S FARM, HENDERSONVILLE, HENDERSON CO., N. C.

Plat No.	TREATMENT	Yield per Acre		Increase	
		Grain, Bushels	Stover, Pounds	Grain, Bushels	Stover, Pounds
1	None	22.6	1680	----------	----------
2	Lime (CaO)	35.7	2400	13.1	720
3	Nitrogen	39.1	3160	16.5	1480
4	Phosphoric Acid	20.6	1680	—2.0	0
5	Potash	20.6	1760	—2.3	240
6	Nitrogen, Phosphoric Acid	53.7	2840	30.8	1320
7	Nitrogen, Potash	37.1	2400	14.2	880
8	None	22.9	1520	----------	----------
9	Phosphoric Acid, Potash	27.3	2280	4.4	760
10	Nitrogen, Phosphoric Acid, Potash	64.3	3840	41.4	2320
11	Lime, Nitrogen, Phosphoric Acid, Potash	70.3	3920	47.4	2400
	Average gain for Nitrogen			25.8	1210
	Average gain for Phosphoric Acid			11.6	410
	Average gain for Potash			3.3	270
	Average gain for Lime (CaO)			9.6	400

There is a striking difference in the results on this field compared to those on the Blantyre field. Here we find no apparent gain from phosphoric acid alone, but nitrogen alone gave an increase of 16.5 bushels. When phosphoric acid was applied in addition to nitrogen we find it gave a large increase. Here, as at the Blantyre field, we find phosphoric acid and nitrogen gave the largest increase, but their relative importance is reversed. Potash alone or in combina-

TABLE 4.—CHEMICAL AND MINERALOGICAL COMPOSITION OF

Labora-tory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2–3 inches....2,000,000 lbs. Subsoil, 28 inches.......8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil	*Inches*					*Percent.*	*Percent.*	
1189	0-7	418	605	34,375	16,750	36	43	Muscovite, biotite, orthoclase, epidote
Subsoil								
1190	9-36	1,524	2,494	75,280	54,034	44	46	Muscovite, biotite, epidote, orthoclase

tion with nitrogen gave slight decreases in yield, but in the case of plats 9 and 10 where applied with phosphoric acid, and with nitrogen and phosphoric acid, the yields were larger than on plats 4 and 5. The increase of number 10 over number 6 is very marked, so much so that it brings up the average gain for potash to 3.3 bushels per acre as compared to a loss of .85 bushel on the Porter's clay.

Lime alone gave an increase of 13.14 bushels and in combination with nitrogen, phosphoric acid and potash, 6 bushels. This large increase in lime is probably due to the liberation of the plant food supply in the soil, especially nitrogen.

Table 4 gives the chemical and mineralogical composition of this field.

The chemical analysis of this soil shows that there is enough potash in the surface 6⅔ inches to furnish a supply for maximum crops for nearly 1,000 years. While the greater part of this potash is in the form of the micas much of it is in the form of the felspars, especially orthococlase. The biotite content here is comparatively fresh in the topsoil, little of it showing alteration to chlorite. This mineral, however, does show alteration in the subsoil. The phosphoric acid content is about the same as in Porter's clay in the Blantyre field, all apatite encountered is the form of inclusions in quartz. The nitrogen supply in this soil will not furnish a one hundred bushel corn crop for over 5 years.

Results on the Buncombe Test Farm.

This farm which contains some 300 acres, is owned and operated by the State Department of Agriculture. It includes a large section of Swannanoa valley land, which is representative Toxaway loam, and considerable tillable upland which is typical Porter's loam. Fertilizer results on this farm should be applicable to extensive areas in practically all the mountain counties of the State.

PORTER'S SANDY LOAM, HENDERSONVILLE TEST FIELD.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Muscovite, biotite, orthoclase	Microcline, zircon, plagioclase, hornblende, magnetite, rutile, chlorite, apatite as inclusions	Zircon, hornblende, plagioclase, magnetite, rutile	Potash bearing minerals are well preserved. Quartz grains are angular to subangular.
Muscovite, biotite orthoclase	Microcline, rutile, zircon, plagioclase, hornblende, pyroxene, chlorite, magnetite	Hornblende, rutile, zircon, chlorite, microcline, plagioclase	Some of the minerals show deep seated chemical alteration. Orthoclase is quite fresh. Quartz subangular, and some secondary.

Toxaway Loam.

Field "A" was established in 1908, but excessive floods destroyed the 1909 crop, so only two years are given. This soil is typical Toxaway loam, and was in corn for each of the three years.

The results are given in table 5.

TABLE 5. RESULTS ON FIELD A, BUNCOMBE FARM, 1908 AND 1910.

No.	TREATMENT	Yield per Acre						Average Increase		Value of Increase	Cost of Fertilizer	Profit
		Grain, Bushels			Stover, Pounds							
		1908	1910	Avr.	1908	1910	Avr.	Grain	Stover			
1	NP	22.7	18.7	20.7	1395	1100	1248	14.2	398	$11.53	$3.66	$7.87
2	NK	5.2	.0	2.6	533	0	267	—3.9	—584	—5.07	2.70	—7.77
3	PK	33.0	21.1	27.1	2565	1360	1963	20.6	1113	18.87	1.50	17.37
4	None	11.0	2.0	6.5	1170	530	850	----	----	----	----	----
5	NPK	37.2	28.5	32.9	2700	1580	2140	26.4	1290	23.64	3.93	19.71
13	None	14.5	3.7	9.1	1710	410	1060	----	----	----	----	----
18	Lime	33.1	13.7	23.4	1725	800	1263	14.3	203	10.82	2.50	8.32
19	Lime, NPK	41.0	36.8	38.9	3289	1780	2535	29.8	1475	26.76	6.43	20.33
17	Manure, P	39.3	28.7	34.0	3000	1460	2230	24.9	1170	22.11	2.79	19.32
Gain for N		4.2	7.4	5.8	135	220	177	----	----	4.77	2.43	2.34
Gain for P		32.0	28.5	30.3	2160	1580	1870	----	----	28.69	1.23	27.46
Gain for K		14.5	9.8	12.2	1305	480	893	----	----	11.97	.27	11.70
Average gain for Lime		11.2	9.5	10.4	302	295	299	----	----	8.48	2.50	5.98

TABLE 6—MINERALOGICAL AND CHEMICAL COMPOSI

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre. Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches--------8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil 1203	*Inches* 0-10	3,160	3,320	33,800	20,560	*Percent.* 46	*Percent.* 54	Biotite, muscovite, epidote
Soil 1204	*Inches* 12-36	2,579	438	135,763	64,873	55	63	Biotite, muscovite, epidote

The same carriers of plant food were used as sources of nitrogen, phosphoric acid and lime as previously stated, but the potash was obtained from manure salt instead of sulphate of potash. The rate of application was on the arbitrary basis of a 7-2½-1½ mixture. Three hundred pounds of this was the amount applied to the normal plat in 1908 and 400 pounds in 1910. This would give 21 pounds of phosphoric acid, 7½ pounds of nitrogen and 4½ pounds of potash per acre in 1908, and 28, 10 and 6 pounds, respectively, in 1910.

It is evident that there were larger increases wherever phosphoric acid was used. In the lower part of the table the amount of increase was obtained by deducting the yield on plat, which received nitrogen and potash, from that on plat 5 which received a complete fertilizer. Thus, on account of the soil of plat 2 being of different character the application of phosphoric acid alone would very probably not have shown so great an increase as this table indicates. Likewise the yield for potash, 12.2 bushels per acre, is too great since it represents the difference between the yield on plat 1 and on plat 5. The same discrepancy arises in the increase of 5.8 bushels due to nitrogen. However, these figures represent the relative importance of the three elements when applied to this dark phase, Toxaway loam.

Lime was applied alone and in combination with nitrogen, phosphoric acid and potash. In both cases it gave material increases in yields as shown by the results on plats 18 and 19. It is of interest to note in this connection that the yield on plat 18 which received lime alone dropped from 33.1 bushels in 1908 to 13.7 bushels in 1910. It is very probable that this temporary beneficial effect of lime alone in 1908 was due to liberation of the plant food of the soil.

In table 6 is found the mineralogical and chemical composition of this soil.

This soil shows an abnormally high potash content and the micas supply practically all this potash in the sand particles. Biotite in

TION OF TOXAWAY LOAM, BUNCOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite	Hornblende, orthoclase, microcline, rutile, zircon, plagioclase, magnetite, apatite as inclusions in quartz	Hornblende, chlorite orthoclase, microcline, plagioclase	Biotite is for the most part fresh. Biotite, epidote and muscovite comprise most of the minerals other than quartz.
Biotite, muscovite	Hornblende, orthoclase, microcline, rutile, zircon, plagioclase	Hornblende, chlorite, orthoclase, microcline, plagioclase, rutile	High percentage of potash bearing minerals. Micas compose principal part. Some biotite altered.

the surface soil is for the most part in a fresh condition, as is usually the case more alteration has taken place in this mineral in the subsoil. In the surface soil there is considerably more phosphoric acid than is usually found in our soils, the principal portion of this element of plant food is in organic form or as inclusions in quartz fragments. It is quite possible that the marked increase in yield on plat 18 where lime was used alone was due to the liberation of phosphoric acid from the organic matter. In the subsoil of this field there is only 438 pounds

TABLE 7. RESULTS ON FIELD B, BUNCOMBE FARM, 1908 AND 1909.

Plat No.	TREATMENT	Yield per Acre: Grain, Bushels 1908	Grain, Bushels 1909	Grain, Bushels Avr.	Stover, Pounds 1908	Stover, Pounds 1909	Stover, Pounds Avr.	Average Increase: Grain	Average Increase: Stover	Value of Increase	Cost of Fertilizer	Profit
1	NP	30.3	20.0	25.2	4470	1335	2903	.2	911	$ 3.78	$ 3.13	$ .65
2	NK	18.6	13.9	16.3	3390	1058	2224	—8.7	232	—5.16	2.31	—7.47
3	PK	34.8	16.7	25.8	2903	930	1917	.8	—75	.26	1.28	—1.02
4	None	33.2	16.8	25.0	2850	1133	1992	--------	--------	------	------	------
5	NPK	41.2	17.6	29.4	3608	1110	2359	4.4	367	4.55	3.36	1.19
13	None	30.1	18.0	24.1	2685	1140	1913	--------	--------	------	------	------
18	Lime	35.6	16.2	25.9	2993	983	1988	1.8	75	1.56	.63	.93
19	Lime, NPK	46.0	21.0	33.5	3315	1230	2273	9.4	360	8.02	4.62	3.40
17	Manure, P	47.4	23.7	35.6	3420	1073	2247	11.5	334	9.39	2.59	6.80
	Gain for N	6.4	.9	3.7	705	180	442	--------	--------	4.36	2.08	2.28
	Gain for P	22.6	3.7	13.1	218	52	135	--------	--------	9.71	1.05	8.66
	Gain for K	10.9	—2.4	4.2	—862	—225	—544	--------	--------	.76	.23	.53
	Average gain for Lime	5.2	.8	3.0	8	—19	—6	--------	--------	2.08	1.26	.82

TABLE 8.—MINERALOGICAL AND CHEMICAL CO

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre (Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches--------8,000,000 lbs.): N	P_2O_5	K_2O	CaO	Minerals Other than Quartz in: Sand	Silt	Abundant Minerals: Sand
Soil 1201	*Inches* 0- 8	1,458	1,726	14,385	2,513	*Percent.* 25	*Percent.* 27	Muscovite, biotite,
Soil 1202	*Inches* 10-36	1,420	776	64,000	11,360	28	33	Biotite, muscovite

of phosphoric acid to a depth of 28 inches which bears out the assumption that most of this material is in the organic form. Nitrogen in this field is also higher than is commonly found in these soils. The lime content here is principally in the form of epidote, with hornblende next, and the plagioclase felspars occurring in small amounts.

Porter's Loam.

Field "B" is located on representative Porter's loam. It consists of 19 plats, with the same plan of treatment as field "A" on the Toxaway loam. The same materials were used and the relative applications for the plats have been the same. However, the normal application was at the rate of 300 pounds per acre for both years.

The plats included in table 5 correspond to those of field "A" in table 3.

We find that phosphoric acid again gives us the largest increase in grain, but the average gain is greater for nitrogen. There is little difference in the average gain in grain for nitrogen, potash or lime. However, though the nitrogen is credited with a gain of 442 pounds of stover per acre, both potash and lime failed to increase the stover over no fertilizer.

Here, as in all the soils examined from this section of the State, there is enough potash to supply the need of crops for many hundred years to come. As in most of these Mountain soils, this potash is held in the form of micas. The biotite content of this field is quite fresh showing little alteration to chlorite or epidote. The potash felspars occur here in limited amounts. In the sand separates there is not over 5 per cent of the minerals other than quartz potash felspars. The amount of phosphoric acid in this field is exceedingly small; that which is found in the mineral form is chiefly as apatite occurring as tiny needles inclosed in quartz grains. This field is fairly well supplied with nitrogen, but for maintaining its fertility, this supply will have

MPOSITION OF PORTER'S LOAM, BUNCOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite	Epidote, chlorite, hornblende, rutile, zircon, apatite as inclusions, plagioclase	Hornblende, chlorite, orthoclase, microcline, plagioclase, magnetite, zircon	Minerals are comparatively fresh. Micas carry by far the greater portion of potash. Apatite is as tiny needles enclosed in quartz.
Biotite	Epidote, hornblende, rutile, zircon, included apatite, magnetite, orthoclase	Hornblende, chlorite, orthoclose, rutile, zircon, plagioclase	More secondary quartz. Otherwise the subsoil is about the same as soil.

to be replenished considerably. The lime content of this soil is held principally as epidote and hornblende. Only a small amount of the lime-soda felspars are here.

Piedmont Soils.

Results at Iredell Test Farm.[6]

This farm is located near Statesville, well up in the Piedmont (foot-hill) section of the State. The main type of soil on the farm is Cecil clay loam. The important types in this section are Cecil sandy loam, Cecil clay loam, and Cecil clay, the latter two predominating.

The Test Plats.

The plats on which these experiments were conducted are embraced in Fields A, B, and C. Fields A and B had been long in cultivation and were badly run down when work was commenced. The plats in Field C were part of an old field, covered with broom sedge, small briars, and small pines in 1903 when the State took hold of the property. These plats are one-twentieth acre in size, with space between plats sufficient for two rows of corn or other crops, the rows on either side of each plat being fertilized like the plat which they adjoin.

Field A.—These plats were used for fertilizer experiments with cotton in 1903-4-6-9; for fertilizer experiments with corn in 1905-7; for general crop of oats without fertilizer in the fall and spring of 1908; and for fertilizer experiments with peas in the summer of 1908. In case of each of the three crops, the same plan or system of fertilization was followed. By this is meant that plat 1 in all cases received only nitrogen; plat 2, phosphoric acid; plat 3, potash, and so on, though the quantities actually applied varied with the three crops. The fertilization of cotton plats was based on a normal application of 400 pounds per acre of a mixture containing 7 per cent available phosphoric acid and 2 per cent each of nitrogen and potash. The fertilization for corn was on a basis of 300 pounds per acre of a mixture containing 7 per cent available phosphoric acid, 3 per cent nitrogen, and 1½ per cent potash. For peas, the fertilization was based on a normal application of 300 pounds per acre of a mixture containing 8 per cent available prosphoric acid, 1 per cent nitrogen and 4 per cent potash.

Field B.—These plats were used for fertilizer experiments with corn in 1903-4-6-8; for fertilizer experiments with cotton in 1905 and 1907; for a general crop of oats without fertilizer in the fall and spring of 1909, and for fertilizer experiments with peas in the summer of 1909.

Field C.—These plats were used for fertilizer experiments with peas in 1904-5-6-7; a grain crop without fertilizer preceding the pea crop in each year except 1904; for fertilizer experiments with cotton in 1908; and for fertilizer experiments with corn in 1909.

Table 9 gives the average results for seven years fertilization for corn on these fields, A, B, and C.

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[6]See N. C. Dept. of Agr. Buls. Vol. 31, Nos. 6 and 8, for details of field results for Iredell farm used in this Bulletin.

Effect of Nitrogen, Phosphoric Acid, Potash, and Lime Alone and in Combination With Each Other on Corn Yields.

The experiments, the results of which are presented in Table 9, were planned to show the effect on the yield of corn of nitrogen (N), phosphoric acid (P), and potash (K) when applied singly, when two of the constituents were applied together, as nitrogen and phosphoric acid (N P), nitrogen and potash (N K), and phosphoric acid and potash (P K), and when all three of these fertilizer constituents were applied to make a complete fertilizer (N P K); also to test the effect of lime (L) when used alone and when used in connection with a complete fertilizer (N P K L).

The results are shown in yields of bushels of shelled corn and pounds of stover per acre for the several years, average yields average increases over the unfertilized (O) plats, which represent the effect of the fertilizer applications, the value of the increase, the cost of the fertilizer, and the value of the increased yield of corn and stover and of corn alone over cost of fertilizer. The value of the increased yield of corn and stover and of corn alone represent the profit from the several fertilizer applications after paying for the fertilizer itself.

In these experiments the corn was cut, shocked and shredded, the stover being all of the plant except the corn on the cob.

Nitrogen, N (Plats 3^2, 1 and 1). During six years the average results on the plats in Fields A and B show decreased yields and in the value of product, while for one year in Field C there was a gain from the use of nitrogen, the average results for the plats in the three fields being an actual loss in both yield and value of product from the application of nitrogen alone. The average annual loss was $1.95 per acre on basis of corn and stover and $1.66 per acre on basis of corn alone.

Phosphoric Acid, P (Plats 4^2, 2 and 2). Phosphoric acid alone produced increased yields in all of the seven years on the plats in the three fields, the average increase for four years in Field B being 6.5 bushels of corn per acre, for two years in Field A 5 bushels, and for one year in Field C 7.4 bushels, or an average for seven years in all three fields of 6.2 bushels, worth at 70 cents per bushel $3.29 per acre for corn alone, or $4.05 for increased yield of corn and stover over cost of fertilizer.

Potash, K (Plats 6^2, 3 and 3). Except the first year in Field B, there was less corn produced on the plats receiving potash alone than on the unfertilized plats, the average for the seven years being slightly less where potash was used than where no fertilizer was applied, and the potash was used at a loss.

Nitrogen and Phosphoric Acid N P (Plats 7^2, 5 and 4). From nitrogen and phosphoric acid increased yields over the unfertilized plats were obtained in all seven years in the three fields, the average annual increase for the four years in Field B being 17.5 bushels of corn per acre; for two years in Field A 22.4 bushels of corn per acre, and for one year in Field C 16.3 bushels, or an average annual

TABLE 9. AVERAGE RESULTS FOR

Number of Plat	FERTILIZER APPLICATION PER ACRE	Pounds of Nitrogen (N) per Acre	Pounds of Phosphoric Acid (P_2O_5) per Acre	Pounds of Potash (K_2O) per Acre	Yield in Bushels of Shelled Corn per Acre		
					1903	1904	1906
5^2–4–8	Unfertilized= ... O=	------	------	------	------	------	------
3^2–1–1	69.2 pounds 13% blood= ... N=	9	------	------	------	------	------
4^2–2–2	150 pounds 14% acid phosphate= ... P=	------	21	------	------	------	------
(5^2+14^2)-4-8	Unfertilized= ... O=	------	------	------	------	------	------
6^2–3–3	22.5 pounds 20% manure salt= ... K=	------	------	4.5	------	------	------
(5^2+14^2)-(4+11)-8	Unfertilized= ... O=	------	------	------	------	------	------
7^2–5–4	69.2 pounds 13% blood= ... N=	9	------	------	------	------	------
	150 pounds 14% acid phosphate= ... P=	------	21	------			
(5^2+14^2)-(4+11)-8	Unfertilized= ... O=	------	------	------	------	------	------
8^2–6–5	69.2 pounds 13% blood= ... N=	9	------	------	------	------	------
	22.5 pounds 20% manure salt= ... K=	------	------	4.5			
(5^2+14^2)-(4+11)-8	Unfertilized ... O=	------	------	------	------	------	------
10^2–8–6	69.2 pounds 13% blood= ... N=	9	------	------			
	150 pounds 14% acid phosphate= ... P=	------	21	------	------	------	------
	22.5 pounds 20% manure salt= ... K=	------	------	4.5			
(5^2+14^2)-(4+11)-8	Unfertilized= ... O=	------	------	------	------	------	------
9^2–7–12^2	150 pounds 14% acid phosphate= ... P=	------	21	------	------	------	------
	22.5 pounds 20% manure salt= ... K=	------	------	4.5			
5^4–18^2–8^2	Unfertilized= ... O=	------	------	------	------	------	------
4^4–14^2–7^2	500 pounds unslaked lime every fourth year ... L=	------	------	------	------	------	------
6^4–15^2–9^2	69.2 pounds 13% blood= ... N=	9	------	------			
	150 pounds 14% acid phosphate= ... P=	------	21	------			
	22.5 pounds 20% manure salt= ... K=	------	------	4.5	------	------	------
	500 pounds unslaked lime every fourth year= ... L=	------	------	------			

—Loss. *By mistake this plat had normal application of potash in 1906. The indications are that this
Checks for plats 5, 6, 7 and 8, Field A, and plats 6^2, 7^2, 8^2, 9^2 and 10^2, Field B, have been obtained from plats
natural fertility between check plats and a corrected check was figured on this basis for each treated plat

increase for seven years in the three fields of 18.8 bushels of corn, worth $10.03 over cost of fertilizer for corn alone, or $13.76 for the increased yield of corn and stover. This was 12.62 bushels more corn, worth $6.74, than phosphoric acid alone produced, showing that nitrogen has added decidedly to the yield and profit when combined with phosphoric acid, though alone it was used at a loss.

Nitrogen and Potash, N K (Plats 8^2, 6 and 5). There were small average increased yields of corn in the three fields from applications of nitrogen and potash combined, the average for the seven years in the three fields being 1.5 bushels per acre, which was not sufficient to pay for the fertilizer This fertilization was therefore at a loss, having cost $1.26 per acre more annually than the value of the increased yield of corn.

SEVEN YEARS IN FIELDS A, B, AND C.

Number of Plat	Yield in Bushels of Shelled Corn per Acre		Yield of Stover in Pounds per Acre					Average Increase in Bushels of Shelled Corn per Acre Due to Fertilizer	Average Increase in Lbs. of Stover per Acre Due to Fertilizer	Value of Increase with Corn at $0.70 per Bushel and Stover at $8.00 per Ton	Cost of Fertilizer per Acre	Value of Average Annual Increase of Corn and Stover Over Cost of Fertilizer	Value of Average Annual Increase of Corn Alone (Not Valuing Stover) Over Cost of Fertilizer
	1908	Ave.	1903	1904	1906	1908	Ave.						
5^2-4-8	------	19.5	------	------	------	------	1785	--------	--------	$------	$------	$--------	$--------
3^2-1-1	------	20.1	------	------	------	------	1712	.6	—73	.13	2.08	—1.95	—1.66
4^2-2-2	------	25.7	------	------	------	------	2003	6.2	291	5.50	1.05	4.05	3.29
(5^2+14^2)-4-8	------	19.1	------	------	------	------	1751	--------	--------	--------	--------	--------	--------
6^2-3-3	------	19.2	------	------	------	------	1781	.1	—113	—.38	.23	—.61	—.16
(5^2+14^2)-(4+11)-8	------	18.5	------	------	------	------	1700	--------	--------	--------	--------	--------	--------
7^2-5-4	------	37.3	------	------	------	------	2633	18.8	901	16.89	3.13	13.76	10.03
(5^2+14^2)-(4+11)-8	------	17.9	------	------	------	------	1650	--------	--------	--------	--------	--------	--------
8^2-6-5	------	19.5	------	------	------	------	1801	1.5	151	1.65	2.31	—.66	—1.26
(5^2+14^2)-(4+11)-8	------	16.8	------	------	------	------	1549	--------	--------	--------	--------	--------	--------
10^2-8-6	------	35.9	------	------	------	------	2308	19.1	1069	17.65	3.36	14.29	10.01
(5^2+14^2)-(4+11)-8	------	16.1	------	------	------	------	1523	--------	--------	--------	--------	--------	--------
9^2-7-12^2	------	3.26	------	------	------	------	2538	16.5	1015	15.61	1.28	14.25	10.27
5^4-18^2-8^2	------	17.6	------	------	------	------	1485	--------	--------	--------	--------	--------	--------
4^4-14^2-7^2	------	16.1	------	------	------	------	1443	—1.47	—42	—1.19	.63	—1.82	—1.66
6^4-15^2-9^2	------	31.8	------	------	------	------	2211	14.2	726	12.84	3.99	8.85	5.95

did not affect the yield, as the average yields for the unfertilized potash plats are near the same.
4 and 11, and 5^2 and 14^2 respectively. It has been assumed that there is a uniform increase or decrease in the between checks.

Phosphoric Acid and Potash, P K (Plats 9^2, 7 and 12^2). Phosphoric acid and potash combined gave increased yields on all the plats in the three fields, the average annual increase for four years in Field B being 15.2 bushels of corn per acre, for two years in A 21 bushels, and for one year in Field C 12.5 bushels, or an average for the seven years in the two fields of 16.5 bushels, worth $10.27 over cost of fertilizer on basis of corn alone, or $14.25 on basis of corn and stover. From this it is seen that potash added to phosphoric acid has increased the yield of corn 10.3 bushels more than phosphoric acid alone, at a profit of $6.98 over cost of fertilizer, showing that potash was effective in corn production on this soil when used in connection with phosphoric acid, but valueless when used alone.

Phosphoric Acid, Potash and Nitrogen, N P K (Plats 10^2, 8 and 6). When all three of the fertilizer materials were used together to make a complete fertilizer, increased yields were obtained on all three plats in the three fields, the average annual increase for four years in Field B being 17.8 bushels of corn per acre, for two years in Field A 21.9 bushels and for one year in Field C 18.7 bushels, or an annual average increase for the seven years in the three fields of 19.1 bushels worth $10.01 over cost of fertilizer on basis of corn alone, or $14.29 on basis of corn and stover.

When compared with each other these results show that nitrogen added to phosphoric acid, potash added to phosphoric acid, and nitrogen and potash added to phosphoric acid have yielded practically the same profits, though nitrogen and phosphoric acid have produced largest average increased yields over unfertilized plats (18.8 bushels per acre), than phosphoric acid and potash (16.5 bushels per acre), and nitrogen, phosphoric acid and potash were larger than either of the other two (19.1 bushels per acre). This indicates that nitrogen is more important on this soil than potash for corn production.

Lime, L (Plats 4^4, 14^2, and 7^2). Lime was applied at the rate of 500 pounds rock or 1,000 pounds slaked lime per acre every fourth year. On the plats in Field B during four years there was a profit of 14 cents per acre from the use of lime On the plats in Field A there was a loss of $9.10 annually per acre, and on the plat in Field C in one year's test a profit of $6.23, the average for the seven years being a loss of $1.66 per acre. The plat in Field C, where there was a profit from the use of lime, had been in peas after grain during four previous years.

Lime with Complete Fertilizer N P K L (Plats 6^4, 15^2 and 9^2). When lime was used in combination with the three fertilizer constituents there was less corn produced on all the plats in Fields B and A than where the three fertilizer constituents were used without lime, but on the plat in Field C, which had previously been in peas and grain for four years, there was a decided gain from the use of lime. As an average of all the tests there was smaller increased yield of corn and profit where lime was used than where it was not.

As an average of all the results, the experiments show—

(1) That nitrogen alone on this soil for the production of corn was used at a loss;

(2) That potash alone had practically no effect on the yield and was used at a loss;

(3) That nitrogen and potash combined increased the yield very slightly but at a loss;

(4) That lime alone, except where peas had been previously grown, was used at a loss;

(5) That phosphoric acid alone gave increased yields and profits in all cases, showing that it is the most important constituent for corn production on this soil;

(6) That nitrogen combined with phosphoric acid added decidedly to the increased yields and profits, the average annual increase for phosphoric acid alone being 6.2 bushels and for nitrogen and phosphoric acid 18.8 bushels per acre;

(7) That potash added to phosphoric acid increased the yields decidedly over phosphoric acid alone, the average annual increase for phosphoric acid alone being 6.2 bushels per acre, and for phosphoric acid and potash 16.5 bushels;

(8) That potash added to nitrogen and phosphoric acid was at a small increase in yield and without profit; and

(9) That the yields from the addition of lime to nitrogen, phosphoric acid and potash were smaller than from the three fertilizer constituents combined.

The most important constituent in producing increased yields and profits on this soil was phosphoric acid. Nitrogen and potash singly or combined, gave good returns when used with phosphoric acid, but were of little or no value when used alone or with each other. Nitrogen added more largely to the yields than did potash.

In table 10 will be found the average mineralogical and chemical composition of plats on Fields A, B, and C.

Though the potash content in this field is much lower than those of the mountain section, we find enough of this element to produce large crops for many years. Here the micas, also furnish much of the potash supply especially in the finer particles of this soil. Orthoclase is very abundant in the sand separates of soils of these plats and it is in a bad state of preservation. The faces present a fibrous looking appearance, resembling an ice crystal as it melts. This soil is supplied with an abundance of lime bearing minerals as epidote, hornblende and the plagioclase felspars. The latter minerals are more abundant than in those fields of the Mountain section examined. The nitrogen supply here is higher than is commonly found in this type of soil, due to the turning under of the pea crop grown on the plats. Phosphoric acid is principally in the organic state, as the amount of apatite found was very small, not enough to anything like furnish the supply shown by the chemical analysis. The apatite found was included in quartz and microcline fragments; in this form it is of very little value for plant use.

Coastal Plain Soils.

Location of Farm and Character of Soil.[7]

The Edgecombe Test Farm is located near the center of Edgecombe County, on the main road between Tarboro and Rocky Mount, approximately eight miles from either place. It is two miles south of Kingsboro Station.

The main upland soil of this farm is representative of much of the Coastal Plain section of the State. It consists of dark gray sandy to fine sandy loam, eight to twelve inches deep, underlain by yellow sandy clay subsoil. The surface soil is light in texture, and is commonly very deficient in organic matter. It classifies as Norfolk sandy to fine sandy loam. Like most of the sandy soils of the Coastal Plain, the sand content is mostly silica which contains no important plant food. The chemical analyses of the soils of this type show them to be

[7] See N. C. Dept. of Agr. Bul., Vol. 35, No. 195 for details of field results of Coastal section.

TABLE 10—MINERALOGICAL AND CHEMICAL ANALYS

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2-3 inches.....2,000,000 lbs. Subsoil, 28 inches=......8,000,000 lbs ..				Minerals Other than Quartz in		Abundant Mine
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil	*Average Inches*	*of 3 samples.*				*Percent.*	*Percent.*	
1193	0-8							
1207	0-8	1,174	1,111	8,287	9,126	33	36	Altered biotite, muscovite, weathered orthoclase
1209	0-8							
Subsoil	*Average Inches*	*of 3 samples.*						
1194	18-36							
1208	"	2,110	7,053	25,741	36,065	32	35	Orthoclase, biotite, muscovite
1210	"							

universally low in nitrogen and phosphoric acid, and in the south-eastern part of the State, also in potash. The potash content is much higher in the northern part of the Coastal Plain section; especially is this true north-east of Albemarle Sound. The soil of the Edgecombe Farm is between these two extremes approaching the lower rather than the high potash content. These light sandy soils are also deficient in lime. This deficiency is noticeable in growing legume crops. Bacteriological investigations show this soil to be very deficient in beneficial bacterial life.

Plats.

The plats at the Edgecombe Farm on which the experiments were conducted are embraced in Fields A and B. The farm on which all the plats are located has been in cultivation for a good many years. The experiments were started on Field A in 1903 and on Field B in 1905. The plats in Field A were laid off in three parallel series of thirteen plats each with a turn row or driveway between each series. The plats are one-tenth acre in size, with an unfertilized space between them sufficient for one row and a four-foot unfertilized space at the end of the rows. Plats, 1, 2 and 3 of the second series and 1, 2, 3, 4, 5, 6, 7 and 8 of the third series of this field are somewhat inferior in fertility naturally to the other plats of the field due to surface washings.

The plats on Field B were laid off similarly to those of Field A, except the plats of the third series were one-twentieth acre in size. Another difference was that in field B provision was made for two rows between plats instead of one, as in Field A and these extra rows were fertilized like the plat nearest to them, but were not

ES OF CECIL CLAY LOAM, IREDELL TEST FARM.

rals in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Altered biotite, muscovite, zircon	Epidote, plagioclase, hornblende, rutile, zircon, magnetite, sillimanite, chlorite microcline	Chlorite, plagioclase, rutile, magnetite, epidote	Minerals show signs of having been badly leached. Much quartz carrying infiltrated iron oxide. Biotite shows alteration especially in the silt. Orthoclase badly weathered.
Weathered orthoclase, muscovite	Epidote, hornblende, chlorite, plagioclase, magnetite, rutile zircon. Included apatite	Epidote, plagioclase, chlorite, magnetite, rutile, zircon	Much quartz carrying infiltrated iron oxide. More orthoclase and muscovite than in soil. Biotite badly altered.

harvested and weighed with the plat. Bur clover was sowed in Field B at the last cultivation of corn in 1908 and of cotton in 1909, but as bur clover failed in 1909 the plats were seeded to crimson clover early in November.

Field A.—The plats were used for fertilizer experiments with cotton in 1903, '04, '06, '08, for fertilizer experiments with corn in 1905, '07, '09. In the case of the two crops the same plan or system of fertilization was followed. By this is meant that, plat 8 in all cases received only nitrogen and potash, plat 9 only phosphoric acid and potash, and so on, though the quantities actually applied varied with the two crops. The fertilization of the cotton plats was based on a normal application of 400 pounds per acre of a mixture containing 7 per cent available phosphoric acid and 2½ per cent each of nitrogen and potash. The fertilization for corn was on a basis of 300 pounds per acre of a mixture containing 7 per cent available phosphoric acid, 3 per cent nitrogen, and 1½ per cent potash.

Field B.—These plats were used for fertilizer experiments with corn in 1906 and 1908 and for fertilization experiments with cotton in 1905, '07, '09.

FERTILIZER MATERIALS USED.

N equals nitrogen at the rate of 10 pounds per acre, or 77 pounds of 13 per cent dried blood;
P equals phosphoric acid at the rate of 28 pounds per acre, or 200 pounds of 14 per cent acid phosphate;
K equals potash at the rate of 10 pounds per acre, or at the rate of 50 pounds 20 per cent manure salt;
L equals lime at the rate of 500 pounds rock or 1,000 pounds slaked lime per acre.

TABLE 11—RESULTS OF FERTILZER EXPERIMENTS WITH COTTON; EFFECT OF NITROGEN, PHOSPHORIC ACID AND POTASH IN DIFFERENT COMBINATIONS; LIME ALONE, AND LIME IN ADDITION TO A COMPLETE FERTILIZER ON FIELD A EDGECOMBE TEST FARM.

Number of Plat	Fertilizer Application per Acre	Pounds of Nitrogen (N) per Acre	Pounds of Phosphoric Acid (P_2O_5) per Acre	Pounds of Potash (K_2O) per Acre	Results in Field A in 1903, '04, '06 and '08 Yield in Seed Cotton in Pounds per Acre 1903	1904	1905	1906	1907	1908	1909	Average Annual Yields of Seed Cotton in Pounds per Acre	Increase in Pounds of Seed Cotton Due to Fertilizer	Value of Increase at 4.5 Cents per Pound	Cost of Fertilizer per Acre	Value of Average Annual Increase Over Cost of Fertilizer
7	Unfertilized O	------	------	------	1,215	1,380	--------	900	--------	625	--------	1,030	------	$------	$----	$----
8	77 lbs. 13% Blood N	10	------	------												
	50 lbs. 20% Manure Salt K	------	------	10	1,410	1,370	--------	1,050	--------	1,030	--------	1,215	185	8.33	2.81	5.52
9	200 lbs. 14% Acid Phosphate P	------	28	------												
	50 lbs. 20% Manure Salt K	------	------	10	1,245	1,185	--------	940	--------	935	--------	1,078	46	2.07	1.90	0.17
10	77 lbs. 13% Blood N	10	------	------												
	200 lbs. 14% Acid Phosphate P	------	28	------	1,220	1,343	--------	1,140	--------	1,070	--------	1,193	163	7.34	4.21	3.13
	50 lbs. 20% Manure Salt K	------	------	10												
10[3]	77 lbs. 13% Blood N	10	------	------												
	200 lbs. 14% Acid Phospahte P	------	28	------	1,358	1,323	--------	990	--------	760	--------	1,108	—9	—.41	3.71	—4.12
8[3]	Unfertilized O	------	------	------	1,248	1,328	--------	990	--------	900	--------	1,117	------	--------	------	------
6[3]	500 lbs. Unslaked Lime every 4th year L	------	------	------	1,245	1,240	--------	960	--------	800	--------	1,061	—56	—2.52	0.63	3.15
7[3]	77 lbs 13% Blood N	10	------	------												
	200 lbs. 14% Acid Phosphate P	------	28	------												
	50 lbs. 20% Manure Salt K	------	------	10	1,568	1,586	--------	1,320	--------	1,290	--------	1,441	324	14.58	4.84	9.74
	500 lbs. Unslaked Lime every 4th year L	------	------	------												
8[3]	Unfertilized O	------	------	------	1,248	1,328	--------	990	--------	900	--------	1,117	------	--------	------	------

RESULTS IN FIELD B IN 1905, '07 AND '09.

	77 lbs. 13% Blood N	10	------	------												
8	50 lbs. 20% Manure Salt K	------	------	10	--------	--------	1,443	--------	1,004	--------	730	1,059	630	$28.35	$2.81	$25.54
	200 lbs. 14% Acid Phosphate P	------	28	------												
9	50 lbs. 20% Manure Salt K	------	------	10	--------	--------	1,273	--------	637	--------	710	873	444	19.98	1.90	18.08
	77 lbs. 13% Blood N	10	------	------												
10	200 lbs. 14% Acid Phosphate P	------	28	------	--------	--------	1,080	--------	690	--------	380	717	288	12.96	3.71	9.25
	77 lbs. 13% Blood N	10	------	------												
11	200 lbs. 14% Acid Phosphate P	------	28	------	--------	--------	1,455	--------	861	--------	750	1,022	593	26.69	4.21	22.48
	50 lbs. Manure Salt K	------	------	10												
13	Unfertilized	------	------	------	--------	--------	630	--------	357	--------	300	429	------	--------	------	------
1³	Unfertilized	------	------	------	--------	--------	545	--------	270	--------	60	292	------	--------	------	------
5³	500 lbs Unslaked Lime every 4th year L	------	------	------	--------	--------	820	--------	600	--------	110	510	218	9.81	0.63	9.18
	77 lbs 13% Blood N	10	------	------												
	200 lbs. 14% Acid Phosphate P	------	28	------												
6³	50 lbs. 20% Manure Salt K	------	------	10	--------	--------	1,265	--------	996	--------	810	1,024	732	32.94	4.84	28.10
	500 lbs. Unslaked Lime L	------	------	------												

The following average prices which fairly represent the cost of the several materials to the farmer for the period under experimentation have been assumed for the materials used:

14 per cent. Acid Phosphate	$14.00
13 per cent. Dried Blood	60.00
14.8 per cent. Nitrate of Soda	50.00
20 per cent. Manure Salt	20.00
Rock Lime	10.00

The following table gives the results of fertilization for cotton on Fields A and B covering a period of seven years.

Nitrogen and phosphoric acid, N P (Plats 10^3 and 10) gave increased yields over the unfertilized plats four of the seven years in Field A being 9 pounds; for four years on Field B an average loss of 288 pounds, or an average increase annually for seven years in the two fields of 167 pounds, worth $3.81 over the cost of fertilizer.

Nitrogen and Potash, N K (Plats 8 and 8). The application of nitrogen and potash combined gave larger increased yields for all seven years except one. The average increase for the seven years was greater than that given by any of the other applications except complete fertilizer and lime. The average profit from this application was $14.11 per acre.

Phosphoric acid and Potash, P K (Plats 9 and 9). Gave a large average annual increase for the three years Field A, 46 pounds, but for the four years on Field B the average increase was 444 pounds. This gives an annual increase on the two fields of 217 pounds, worth $9.81, which is $7.87 more than the cost of the fertilizer.

Phosphoric Acid, Potash and Nitrogen, N P K, (Plats 10 and 11). These materials combined in a complete fertilizer gave average increased yields in both fields. The average annual increased yields for the four

TABLE 12—MINERALOGICAL AND CHEMICAL ANALYSES OF

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2-3 inches....2,000,000 lbs. Subsoil, 28 inches.......8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil	*Average of 3 samples.*							
	Inches					*Percent.*	*Percent.*	
1239, 1243, 1245	0- 8	853	953	3,087	3,220	5 to 7	8 to 10	None.
Subsoil	*Average of 3 samples.*							
	Inches							
1240, 1246, 1254	18-36	1,360	1,573	11,453	8,880	5 to 7	8 to 10	None.

years on Field A was 163 pounds of seed cotton; and for three years on Field B, 593 pounds; or an average increase per acre for the seven years of 348 pounds, worth $11.45 over the cost of fertilizer.

Lime, L. (Plats 6^3 and 5^3). For the four years on Field A the lime plat showed an average annual loss of 56 pounds of seed cotton, representing a financial loss of $3.15. On field B however, this material gave an increase each of the three years, averaging 218 pounds more than the unfertilized plat, and a profit of $9.18. As an average of these two apparently contradictory results lime gave an average of 62 pounds representing a profit of $2.16.

Lime and complete fertilizer, N P K L, (Plats 7^3 and 6^3). With the exception of the year 1905 on Field B lime in combination with the three fertilizer constituents gave a larger yield of cotton than did complete fertilizer without the lime. The average yield for the seven years from this treatment was 142 pounds greater than for complete fertilizer without lime. The profit, $17.62, is greater than that from any of the other fertilizer combinations.

Taking the experiments as a whole, the average results show that:

The combination of nitrogen and phosphoric acid gave the smallest increase and also the least profit.

That nitrogen and potash gave an average yield of 209 pounds more seed cotton than did the nitrogen and phosphoric acid treatment, with a profit of $14.11.

Phosphoric acid and potash gave a slightly greater yield than nitrogen and phosphoric acid, but not nearly as great as nitrogen and potash.

Nitrogen added to phosphoric acid and potash making a complete fertilizer, increased the yield 131 pounds, and gave an additional profit of $3.58.

The results from lime while contradictory on the two fields, show a

NORFOLK FINE SANDY LOAM—EDGECOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
None.	Orthoclase, weathered and fresh, microcline, epidote, zircon, magnetite, chlorite, muscovite, hornblende	Orthoclase, microcline, epidote, chlorite, chloritized biotite	Potash accurs as felspars mainly, only trace of muscovite, and chloritized biotite. Lime is as epidote, almost entirely. Very little hornblende present. Quartz badly worn.
None.	Orthoclase, microcline, epidote, zircon, chlorite, magnetite diatoms	Orthoclase, microcline, epidote, zircon, chlorite, muscovite, hornblende	Very little difference between soil and subsoil in mineralogical composition. Slightly more micas in subsoil.

slight average increase and a profit of $2.16. In addition to complete fertilizer, lime shows an increase of 251 pounds of seed cotton, and its application here was at a profit of $6.17, and for the complete application—LNPK, the profit was $17.62.

The main increase yields and profits came from nitrogen and potash. On the whole, practically no beneficial effect was seen from the application of phosphoric acid. The application of lime was in general, accompanied with some profit.

Table 12 gives the average mineralogical and chemical composition of three samples of soil taken from the Edgecombe Farm.

The chemical analyses show that the soil from this farm is low in nitrogen and phosphoric acid, and compared to most of the Piedmont and Mountain soils, low in potash and lime. The mineralogical analyses show that the supply of potash is held mainly in the felspars; there being only a trace of muscovite in the sands and little more in the silt separates. What biotite found in the silt has been altered for the most part. Much of the orthoclase found here has been weathered, but microcline presents pure clean faces and sharp edges showing that little decomposition has taken place. Though the chemical analyses show that there is about 3,000 pounds of potash compounds per acre in this soil, the field results for seven years indicate that this element can be applied with profit. This fact bears out somewhat the conclusions drawn by other investigators as to the availability of potash when held in the form of felspar. In this soil the greater part of the orthoclase shows such marked signs of chemical decomposition, that it is reasonable to assume that microcline furnishes the greater part of the potash here.

The Mountain and Piedmont soils, experimented with, have the micas as their principal source of potash. In these soils the amount of organic matter is little higher than that from the Edgecombe Farm. It would not seem probable that the difference in the potash requirements are due to the amount of decaying organic matter liberating more potash in the Piedmont and Mountain soils and not so in this soil from the Coastal Plain. The difference must be due to the way the potash is held in these soils.

Lime is supplied to the soil from the Edgecombe Farm almost entirely as epidote, there being only a trace of hornblende, and no plagioclase felspar present. The field results obtained on this farm indicate that lime can be used here at a profit, whereas the chemical analyses show that the surface soil to a depth of 6⅔ inches contains some 3,000 pounds of this material.

In this soil the supply of phosphoric acid is very low, that which is present is in other forms than the mineral apatite. Most careful examinations have failed to show this mineral in a single instance.

SUMMARY

The field results obtained on experimental farms show that there is a close relation between the chemical and mineralogical composition and the fertilizer requirements of the soils under experiment. The chemical analyses are of value in determining the total amount of the various elements of plant food which the soil contains, and the mineralogical analyses supplementing the chemical analyses, show to a great extent in what way these elements are combined.

The soils of the Mountain and Piedmont sections of the State are, as a rule, better supplied with potash, lime, and phosphoric acid than are those of the Coastal Plain.

The micas furnish to a much larger extent the potash supply in the former two sections than they do in the latter. In a great many of the Mountain soils muscovite and biotite are the main sources of potash, and in a majority of these soils the biotite content is well preserved. The potash felspars are much more abundant in the soils of the Piedmont Plateau than they are in the Mountain section, however, the micas furnish much of the potash for these soils. In the Coastal Plain soils, orthoclase and microcline supply most of this material, and it is on these latter soils that the greatest response is secured from the use of potash fertilizers, as shown by the field results thus far published.

The phosphoric acid content of most North Carolina soils is low. Much of this element of plant food is found as apatite included in quartz and other minerals. In this form it is doubtful if the plant can draw its supply of phosphoric acid, certainly not for many years to come. The soils of the Coastal Plain carry their main supply of phosphoric acid in other forms than apatite, for in very few instances has this mineral been encountered in soils from this section.

Lime in the Coastal Plain soils is for the most part in a less available form for crops than much of that found in the sections higher up in the State. The former soils derive their main supply of lime from epidote. In the Piedmont and Mountain portions hornblende and the plagioclase felspars are found in larger quantities than in the Eastern section. The amount of the plagioclases has never been large, except in the soils of the Iredell series. There they are found in some quantity.

In the mineralogical composition as a rule there is little difference between the soil and subsoil. This may be due to the depth to which the samples were taken.