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FERTILIZERS FOR COTTON.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., March 6, 1894.

SIR: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on fertilizers for cotton, compiled by J. M. McBryde, PH. D., from accounts of experiments carried on under his direction for several years on the farms of the South Carolina Experiment Station. It is believed that the wide circulation of this information in the Southern States will do much to prevent unnecessary expenditures for commercial fertilizers, which now constitute a great burden on the cotton planters.

Respectfully,

A. C. TRUE,
Director.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

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FERTILIZERS FOR COTTON.

INTRODUCTORY.

We have reason to believe from extended observation and experience in the field that hundreds of thousands of dollars are annually wasted by farmers in the lavish and injudicious application of fertilizers on cotton. In soils abounding in potash, potassic fertilizers, such as kainit, muriate of potash, etc., are often unnecessarily applied at a cost amounting to $4 or $5 per acre. It is especially timely at this season, when the farmers are about to plant their crops for the year, to discuss the manurial requirements of cotton, and to give in condensed form the results of careful and long-continued experiments bearing directly upon this question. The subject is so broad as to require subdivision. It will, therefore, be discussed under the following heads: Does cotton require potash, phosphoric acid, and nitrogen? If so, in what amounts and in what forms? Does it need lime? Will copperas prevent its rusting? At what time or times should nitrate of soda be applied? How should the fertilizers be applied?

DOES COTTON REQUIRE POTASH, PHOSPHORIC ACID, AND NITROGEN?

It is now held that potash, phosphoric acid, and nitrogen are the three most important constituents of manures, and the only ones generally called for by soils. In most soils there is a sufficiency of the other elements of plant food—such as lime, magnesia, soda, sulphur, iron, etc. In a limited number, lime is sometimes deficient. It can, however, be easily supplied by cheap forms of calcareous manures.

In beginning experimental work bearing upon these questions a few years ago, when director at the South Carolina Experiment Station, we had little in the way of published information to guide us. It was generally believed that cotton required phosphoric acid, but opinion was divided as to the importance of potash and nitrogen. In deciding upon the amount of each constituent to be used in our tests several courses were open to us: To take arbitrary amounts of each; to accept the percentages of the ammoniated acid phosphates offered for sale in our markets; or to employ the amounts contained, according to analysis, in a crop yielding a given weight of lint per acre. The last was preferred as offering a convenient working hypothesis, with the full knowledge of the fact that in determining the manurial requirements of any crop analysis is not an infallible guide. It was considered better, however, than a mere rule of thumb.

We found, to our disappointment, that the published analyses of the parts of the cotton plant were, with the exception of those of the seed, all old and probably unreliable. We were obliged to use them in lieu of anything better, but began at once an elaborate series of analyses and determinations of our own.

According to the old analyses, the plants of a crop of cotton yielding 300 pounds of lint per acre contain 52 pounds of nitrogen, 26 pounds of phosphoric acid, and 48 pounds of potash. These amounts we assumed to be the full applications or doses required to produce a crop giving 300 pounds of lint per acre. Where not otherwise stated, these amounts were supplied as follows: The nitrogen by 330 pounds of nitrate of soda (containing 16 per cent of nitrogen); the phosphoric acid by acid phosphate (containing 16 per cent of phosphoric acid—about 15 per cent available and 1 per cent insoluble); the potash by muriate of potash (containing 50 per cent of potash).

In the following pages the full dose of any constituent is conveniently represented by the numeral 1 placed before its name; 1 nitrogen, for example, means 52 pounds nitrogen (furnished by 330 pounds of nitrate of soda, etc.), 1 potash means 48 pounds of potash, etc. Smaller or larger amounts are expressed in the same way: 2 phosphoric acid means a double dose or 52 pounds of phosphoric acid, ½ potash means the half dose or 24 pounds of potash, etc.

Several plats were left unfertilized, some received only one constituent, others received two constituents, and others, again, all three constituents. The full dose of a constituent was used in every case. Each test was continued on the same plats from year to year. Every test was carefully duplicated, the two plats being separated from each other in the experimental field by considerable intervals.

The station had two farms, situated in different sections of the State. Every test was separately made at each farm and carefully repeated for three years. This duplication and repetition gave us valuable data for verifying and correcting results. The missing plants in every plat were carefully determined and allowed for in order to reduce the plats to a uniform stand. By close observation the amount of error incident to the work—errors due to differences in the mechanical and chemical condition of the soils in the plats employed and numerous accidental causes—was accurately determined. This error averaged ± 30 pounds of lint cotton per acre for the three farms in 1888, ± 32 pounds in 1889, and ± 32 pounds in 1890, making an average of ± 31 pounds for the three years.

From an examination of the soils of the two farms and inquiry as to their history it was assumed, at the beginning of our tests, that the particular soils to be experimented on would give, without manures of any kind, about 50 pounds of lint per acre. The results showed that the unfertilized plats, thoroughly prepared and cultivated, gave somewhat better returns than this. The soils selected were very thin, being greatly exhausted by years of improvident tillage.

The agreement in the results of the tests on the two farms is so remarkably close as to show the controlling influence of the plant, and therefore to justify us in using the combined averages of the two farms:

Combined annual average yields of lint per acre on two farms for three years.

Fertilizer.	1888.	1889.	1890.	Average of three years.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Unfertilized	08	83	73	85
Fertilized with—				
Potash	120	83	01	98
Phosphoric acid	108	156	154	159
Nitrogen	109	73	114	99
Potash and phosphoric acid	191	192	171	185
Potash and nitrogen	180	161	168	170
Phosphoric acid and nitrogen	203	206	240	216
Potash, phosphoric acid, and nitrogen	298	316	339	318

Taking the averages of the unfertilized plats as unity, the comparative average results of the several applications for the three years can be conveniently shown as follows:

Comparative average yields of lint for three years.

Fertilizer.	Upper farm.	Lower farm.	Two farms.
Unfertilized	1.00	1.00	1.00
Fertilized with—			
Potash	0.96	1.31	1.14
Phosphoric acid	2.00	1.78	1.89
Nitrogen	1.58	0.83	1.20
Potash and phosphoric acid	2.19	2.16	2.17
Potash and nitrogen	1.93	2.05	1.99
Phosphoric acid and nitrogen	2.74	2.40	2.54
Potash, phosphoric acid, and nitrogen	4.02	3.52	3.77

The combination of potash, phosphoric acid, and nitrogen gave an average increase, as compared with the averages of unfertilized plats, of 300 per cent at the upper farm and 250 per cent at the lower, and an average yield of about 100 pounds more lint per acre than any combination of two of these materials. The figures leave no doubt as to the importance of potash, phosphoric acid, and nitrogen to cotton.

A careful study of the detailed results of the tests may be condensed into the following table, which shows the gain in pounds of lint per acre afforded by adding any one constituent to the unfertilized plats, or to either of the other constituents, or to both:

Increase in yield of lint per acre from applying each of the fertilizing constituents alone or combined with the other two.

Fertilizing constituent added.	Unfertilized.	Potash.	Phosphoric acid.	Nitrogen.	Potash and phosphoric acid.	Potash and nitrogen.	Phosphoric acid and nitrogen.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Potash	13	....	26	71	....	....	102
Nitrogen	14	72	57	....	133	....	....
Phosphoric acid	74	87	....	117	....	158	....

It will be seen that the nitrogen gave better results than the potash, and the phosphoric acid better results than the nitrogen. Taking the combined average of the combination of any two of the constituents as one, the effect of adding the third may be expressed as follows: Potash 1.47, nitrogen 1.72, phosphoric acid 1.87. It is clear from these figures that phosphoric acid was of greater relative importance to the cotton crop than nitrogen, and nitrogen of more importance than potash.

PROPORTIONS AND AMOUNTS OF POTASH, PHOSPHORIC ACID, AND NITROGEN REQUIRED.

Our applications, it will be remembered, were intended for a crop yielding 300 pounds of lint per acre. While the results of the foregoing tests leave no doubt as to the importance of potash, phosphoric acid, and nitrogen, it does not necessarily follow that the amounts supplied were the right ones. The full or theoretical dose may well have been too small on the one hand or too large on the other. In order to determine this point other series of experiments were carried on in which different amounts of each constituent were employed. In one series different amounts of potash were used with full doses of the other constituents; in another series the phosphoric acid, and in a third the nitrogen varied, the other two remaining the same. For convenience the two constituents remaining fixed (as to amounts used) in a series may be called the constants, and the one changing the variant. In stating the results the average yield of lint per acre for the two farms for the three years is given.

POTASH.

In this series phosphoric acid and nitrogen were the constants and potash the variant. Full, double, and half doses (48 pounds, 96 pounds, and 24 pounds) of potash were tested, with full doses of phosphoric acid and nitrogen, with the following results:

	Pounds.
2 potash	329
1 potash	318
½ potash	294

It will be seen that the double dose gave only 9 pounds more than the full dose, and the latter only 24 pounds more than the half dose. The average probable error for the two farms amounted to ±31 pounds of lint per acre. It appears, therefore, that the several amounts gave about the same average results. It has already been mentioned that the potash in this series of tests was supplied by muriate of potash. In another series—which will be discussed later on—undertaken for the purpose of determining the relative values of the several kinds of potassic manures, different amounts of potash were also tested in the form of kainit and sulphate of potash. The full dose of potash in the kainit gave 331 pounds and the half dose 332 pounds; the full dose in sulphate of potash gave 322 pounds and the half dose 295 pounds. With kainit there was a difference of 1 pound in favor of the half dose; with the sulphate of potash, a difference of 27 pounds in favor of the full dose.

The results of the one series strongly support those of the other, and we must, therefore, conclude that the full and double doses of potash were excessive.

PHOSPHORIC ACID.

In this series potash and nitrogen were the constants and phosphoric acid the variant. Full, double, and half doses (26 pounds, 52 pounds, and 13 pounds) were tested together with full doses of potash and nitrogen. The phosphoric acid was supplied by acid phosphate.

	Pounds.
2 phosphoric acid	386
1 phosphoric acid	398
½ phosphoric acid	277

The mean difference between the averages of the double and full doses was 68 pounds for the two farms. The difference between the full and half doses averaged 41 pounds for the two farms. Increasing the dose by 100 per cent seems to have been attended with a corresponding increase of from 65 to 75 pounds of lint. Indeed, increasing the amount of phosphoric acid produced marked effects at the two farms both in this series and in another series of experiments with different phosphatic fertilizers. In the latter series the full dose of phosphoric acid in reduced phosphate (see p. 16) averaged 44 pounds more lint than the half dose for the two farms. It follows, therefore, that double doses of phosphoric acid can be advantageously employed.

NITROGEN.

In this series nitrogen was the variant and phosphoric acid and potash the constants. As nitrogen is the most expensive constituent of fertilizers, it was thought advisable to test it in several different proportions, with full doses of the others. The nitrogen was supplied by nitrate of soda. The full dose amounted to 52 pounds.

	Pounds.
2 nitrogen	269
1½ nitrogen	257
1 nitrogen	318
¾ nitrogen	316
½ nitrogen	269
¼ nitrogen	232

The close parallelism between the results of the tests at the two farms was remarkable. It will be seen that the full and three-quarter doses gave almost exactly the same combined averages—318 pounds and 316 pounds, respectively—and better results than the heavier doses, which probably lowered the yield, as compared with the full dose, by inducing too luxuriant a growth of stem and foliage, or what is commonly known as *weed*. The half dose gave exactly the same yield as the double dose. Reducing the dose by more than 50 per cent unmistakably diminished the yield, as will appear from a comparison of the average of the full and quarter doses. As compared with the quarter dose, the half dose does not show an increase sufficient to make up for its additional cost. That the full dose of nitrogen was excessive, as compared with the half dose, also appears from the results of another series of experiments with different nitrogenous manures in which full and half doses of nitrogen were employed. In that series the half dose of nitrogen in dried blood gave 6 pounds more lint than the full dose, in the cotton-seed meal 33 pounds more, and in the ground cotton seed 7 pounds more.

It follows, therefore, that the three-quarter, full, one and one half, and double doses were excessive, and that the difference in favor of the half dose as compared with the quarter dose was not sufficiently large to meet its additional cost.

The results of the preceding tests taken together show that a crop of cotton yielding 300 pounds of lint per acre requires double the full or theoretical amount of phosphoric acid, but only about one fourth to one half the full amounts of potash and nitrogen.

DOUBLE DOSES OF TWO CONSTITUENTS.

In all the foregoing series of tests except one, two of the constituents were constants, while the third was increased or diminished. It was deemed advisable, in order to test the effect of increasing the amounts of the two minerals (potash and phosphoric acid), or nitrogen and one mineral, to carry on another series in which one constituent should be taken as the constant and the other two as the variants. This series was also intended to be a check upon those discussed above. To present the results more clearly, the double doses of the two constituents will be compared with the double and also with the single doses of each.

	Pounds.
1 potash and 1 phosphoric acid	318
2 potash and 1 phosphoric acid	329
1 potash and 2 phosphoric acid	386
2 potash and 2 phosphoric acid	358

(1) *Double doses of the minerals.*—In the tests under this head the full dose of nitrogen was used in each case and is, therefore, not mentioned in the comparison. In this and the two following statements of results of yield of lint per acre the first three tests are taken from the preceding series.

It is evident that doubling both minerals gave no better returns than doubling only the phosphoric acid, for the difference between the averages of the two applications did not exceed the probable error at either farm. Their beneficial effects as compared with those of the other two were doubtless due in both cases to the increased dose of phosphoric acid.

(2) *Double doses of nitrogen and potash.*—In these tests phosphoric acid (full dose) was the constant.

	Pounds.
1 nitrogen and 1 potash	318
1 nitrogen and 2 potash	329
2 nitrogen and 1 potash	269
2 nitrogen and 2 potash	268

Double doses of nitrogen and potash gave almost exactly the same results at each farm as the full or single dose of nitrogen, and both applications were inferior to the first two, in which single doses of nitrogen were used. Here, again, there is evidence of the injurious effects of excessive doses of nitrogen. The fruit requires phosphoric acid. The heavy growth of weed induced by the excess of nitrogen consumes a large part of the phosphoric acid, when it is present in limited amounts, and the supply fails before the plant has perfected all its fruit. The unseasonable growth is also generally checked or destroyed by cold weather. It follows from this that whenever heavy amounts of nitrogen are employed the phosphoric acid should be correspondingly increased. This statement is borne out by the results of the next tests.

(3) *Double doses of nitrogen and phosphoric acid.*—Potash (full dose) was the constant. The yield of lint per acre was as follows:

	Pounds.
1 nitrogen, 1 phosphoric acid	318
2 nitrogen, 1 phosphoric acid	269
1 nitrogen, 2 phosphoric acid	386
2 nitrogen, 2 phosphoric acid	405

The difference in the effects of the double dose of nitrogen when combined with the double dose and the single dose of phosphoric acid is very striking and abundantly confirms the point made above. The double dose of phosphoric acid gave about the same combined average as the double dose of nitrogen and phosphoric acid. Both show decided gains as compared with the applications containing single doses of nitrogen and phosphoric acid.

The conclusions drawn from the results of the experiments discussed under the preceding heads are still further strengthened by the results of this series of tests.

DOUBLE DOSES OF THREE CONSTITUENTS.

The point may be made, Would not doubling all three constituents give better results than doubling any two of them? Our tests answer it as follows:

	Pounds.
1 potash, 1 phosphoric acid, 1 nitrogen	318
2 potash, 2 phosphoric acid, 2 nitrogen	320

On comparing their combined averages it is apparent that the two applications gave about the same results. It will be asked, Why did doubling all three constituents fail to show any increase, when doubling the phosphoric acid, or even the phosphoric acid and nitrogen, was of such decided benefit to the crop? It can be replied that the excessive applications of potassic and nitrogenous salts (muriate of potash and nitrate of soda) probably acted injuriously upon the crop, especially in the early stages of its growth, and thereby neutralized the beneficial effects of the phosphoric acid. The deficiency of the soils in vegetable matter seriously affected their relations to heat and moisture and unfitted them to respond to heavy applications of commercial fertilizers or chemicals.

In their advocacy of the intensive system of farming some go so far as to claim that "doubling the manure will double the crop." No amount of food will fatten a very lean animal in a few weeks' time. And so with an impoverished soil. It can not be forced into immediate fertility by lavish applications of commercial fertilizers. Its mechanical condition—its physical properties—must be improved by thorough tillage and the addition of vegetable matter. The results of the foregoing experiments show the necessity of caution in the use and application of manures, for they make it clear that with a given amount of phosphoric acid only comparatively small doses of potash and nitrogen were needed and that all amounts of potash and nitrogen in excess of these doses were simply thrown away.

It will be of interest to compare with the above test another in which double doses of the three constituents were employed in connection with vegetable matter. Six tons of good stable manure supply the full or theoretical doses of the three constituents, together with a large amount of humus. Twelve tons will furnish double doses of the three. These two amounts were tested in the series of experiments with nitrogenous manures to be discussed later on. Their average results of yield of lint per acre may be given here as follows:

	Pounds.
1 potash, 1 phosphoric acid, 1 nitrogen (stable manure)............	392
2 potash, 2 phosphoric acid, 2 nitrogen (stable manure)............	462

Comparing the combined averages of stable manure and the commercial fertilizers it will be seen that in the former the single doses of the three constituents gave 74 pounds more lint and the double doses 142 pounds more than the corresponding doses in the latter. The difference in favor of the stable manure is, in large part, attributable to the beneficial effects of its humus. Comparing, next, the combined averages of the two applications of stable manure we find that doubling the dose, so far from doubling the crop, only gave an increase of 70 pounds of lint. The increase was by no means commensurate with the increased cost of the application. The results of our tests are not opposed to the judicious use of liberal amounts of manures, but only to their lavish and unintelligent employment. The enrichment of an impoverished soil is the work not of months but of years, and it can only be economically accomplished in our climate by turning under green crops and other forms of vegetable matter in connection with applications of fertilizers.

But it may be claimed that heavy applications of fertilizers are cumulative in their effects and will, therefore, pay in the long run. Our observations, covering a period of three years, showed that this was not the case at our farms.

IN WHAT FORMS CAN POTASH, PHOSPHORIC ACID, AND NITROGEN BE MOST EFFECTIVELY SUPPLIED?

Numerous kinds of potassic, phosphatic, and nitrogenous manures are now offered for sale in our markets. Under the first head are generally classed wood ashes, cotton-seed hull ashes, kainit, sylvinit, muriate of potash, and sulphate of potash; under the second, floats, basic slag, bone meal, boneblack, dissolved boneblack, acid phosphate or superphosphate of lime, and phosphatic guanos; under the third, sulphate of ammonia, nitrate of soda, dried blood, fish scrap, tankage, cotton-seed meal, and guanos. When the variety offered is so great the determination of the relative values of the several kinds in each class becomes a matter of importance.

Our tests were confined to the kinds commonly used in the South. The experiments included tests of potassic manures, tests of phosphatic manures, and tests of nitrogenous manures. In each series equivalent amounts of the several fertilizers were used, that is, amounts furnishing the same number of pounds of the given constituent. The percentage of potash, phosphoric acid, or nitrogen in the kinds tested was determined beforehand. Care was taken to use liberal amounts in order to allow for possible loss in their handling or application. It is known that nitrogen, phosphoric acid, and potash are more available (to the plant) in some forms than in others. In order to determine this point, as well as to check the tests of the preceding series, two amounts of each fertilizer were employed—one containing the full and the other the half dose of the given constituent.

POTASSIC MANURES.

Three kinds of potassic manures were tested—muriate of potash, containing 50 per cent of potash, sulphate of potash containing 37 per cent of potash, and kainit containing 12 per cent of potash. Equivalent amounts of each were employed. The cost of the potash in each kind will be given later on; here we are only concerned with their effects upon the crop. The full doses of phosphoric acid and nitrogen were supplied, as in the preceding series, by acid phosphate and nitrogen. These two being the constants are omitted for the sake of clearness in the statement. The effects of the full dose of potash in the three (potassic) fertilizers will first be compared.

	Pounds.
Muriate of potash	318
Sulphate of potash	322
Kainit	331

The agreement in the combined averages of the three applications is very close.

It may be objected that potash is possibly less active in some one or more of the salts and that the amount of the fertilizer used will therefore affect its results. To meet this point, equivalent amounts supplying the half dose of potash were also tested with the following results:

	Pounds.
Muriate of potash	269
Sulphate of potash	295
Kainit	332

The agreement in the combined averages is again close, for the difference between those of the kainit and the sulphate does not exceed the probable error.

It follows from these results that the three kinds may be indifferently used for supplying the required dose of potash.

These tests were also intended to check those of the preceding series. Their results were referred to under that head and it will be sufficient to give here only their combined averages.

Combined average yield of lint per acre for three years.

Fertilizer.	Muriate of potash.	Sulphate of potash.	Kainit.
	Pounds.	*Pounds.*	*Pounds.*
1 potash	318	322	331
½ potash	294	295	332

In each case the half dose was practically as effective as the full dose.

PHOSPHATIC MANURES.

Experiments with phosphatic manures are not as simple as those with potassic. Whatever may be true of potash, it is certain that some forms of phosphoric acid are more soluble, and hence more available to the plant, than others. In acid phosphate, dissolved boneblack, etc., the phosphoric acid is readily soluble; in reduced or precipitated phosphate it is slowly soluble; in basic slag, floats, coarse bones, etc., it is insoluble (in water or weak acids). Our experiments bear upon the relative values of these three classes of phosphatic manures.

Three forms of phosphoric acid are recognized by the fertilizer control stations and have different money values assigned them—the soluble, the reverted (slowly soluble), and the insoluble. The first two are generally classed together as available. There is great difference of opinion as to the relative agricultural value of these three forms. For a time it was held that to be of value to the plant phosphoric acid must be readily soluble, hence the slowly soluble form was held to be of little account. Afterwards it was discovered that the soluble form when applied to the soil was precipitated by its bases, such as alumina, iron, etc., and converted into the dicalcic or slowly soluble form, also called the reduced or reverted. Some contend that the precipitated or reverted acid is, for this reason, as available to the plant as the soluble. It is replied that the solubility of a fertilizer is largely determined by its fineness of division, and, granting that the soluble acid is immediately dissolved by the waters of the soil and precipitated, this solution and subsequent precipitation secures a thoroughness of distribution and fineness of division that can not be effected by mechanical means. The advocates of the reverted acid urge, however, that the soluble form is often taken up by the crop before it is precipitated and that its acidity is injurious to the plant. In favor of the basic or insoluble form it is asserted that it is gradually dissolved by the reagents of the soil and rendered available and that it is consequently of value to crops of comparatively slow growth. It is of interest, therefore, to collect data bearing upon these points.

All three forms of phosphoric acid were tested at the two farms. The soluble form was supplied by acid phosphate containing 16 per cent total phosphoric acid (about 11 per cent soluble, 3¼ per cent reverted, and 1¾ per cent insoluble). The reverted form was supplied by reduced phosphate. This was made by mixing acid phosphate and floats in the proportion of 2 pounds of the former to 1 pound of the latter and allowing the mixture to stand for some weeks until the soluble phosphoric acid was precipitated. The reduced phosphate contained 19.5 per cent total phosphoric acid (about 10 per cent available, the rest insoluble). The insoluble form was supplied by basic slag, containing 21.5 per cent phosphoric acid, and also by floats, containing 26.5 per cent phosphoric acid. It is claimed for the slag that its phosphoric acid is more easily rendered available by the solvents of the soil than other insoluble forms.

The acid phosphate contains, in addition to its phosphate of lime, a large amount of sulphate of lime. This sulphate sometimes acts beneficially on certain soils on account of its lime. Hence it is usual in experiments with different classes of phosphatic manures to have one or more plats dressed with plaster or sulphate of lime in order to test the relations of the soil to lime. As we had a series of tests of calcareous manures running alongside of this one which bore on this very point, sulphate of lime plats were omitted. Such amounts of the different phosphatic fertilizers were used as would supply the full dose (26 pounds) and also the half dose (13 pounds) of phosphoric acid. These were employed with full doses of potash and nitrogen. Comparing, first, the effects of the full dose of phosphoric acid in different forms, we have:

	Pounds.
Acid phosphate	318
Reduced phosphate	249
Floats	204
Basic slag	194

The two insoluble phosphates—slag and floats—gave about the same average results. As compared with their combined averages the reduced phosphate shows a gain of about 45 pounds of lint. The acid phosphate gave 69 pounds more than the reduced phosphate and 112 pounds more than the floats. It is clear that the results were directly proportionate to the solubility of the phosphoric acid—the more soluble the acid the larger the average yield of lint. The floats and slag gave no better results than acid phosphate (with soluble phosphoric acid) and potash without nitrogen, or acid phosphate and nitrogen without potash.

The half doses of phosphoric acid gave the following results:

	Pounds.
Acid phosphate	277
Reduced phosphate	205
Floats	171
Basic slag	188

The average results of the half doses agree very closely with those of the full doses. The acid phosphate shows 72 pounds more lint than the reduced phosphate and 106 pounds more than the floats.

As to the comparative effects of the full and half doses it appears that in the insoluble forms, floats and slag, one dose was about as effective as the other, both being apparently of little benefit to the crop; for allowance must be made for the nitrogen and potash with which they were combined. In the slowly soluble form, reduced phosphate, the full dose gave 44 pounds more than the half dose; in the soluble form, acid phosphate, it gave 31 pounds more than the half dose.

NITROGENOUS MANURES.

Two forms of nitrogen are recognized by agricultural chemists—organic nitrogen, contained in matters of vegetable or animal origin, such as stable manure, cotton-seed meal, dried blood, fish scrap, etc.; and inorganic nitrogen, contained in mineral matters, such as sulphate of ammonia, nitrate of soda, nitrate of potash, etc. In the following tests the inorganic nitrogen was furnished by nitrate of soda, containing 16 per cent of nitrogen, and the organic nitrogen by dried blood, containing 12½ per cent of nitrogen, cotton-seed meal containing 7 per cent of nitrogen, cotton seed containing 2½ per cent of nitrogen, and stable manure containing 0.45 per cent of nitrogen. Tests were made of both ground and unground cotton seed. Mixed nitrogen (about one half organic and one half inorganic) was furnished by a mixture of stable manure and nitrate of soda. Cotton-seed meal, cotton seed, and stable manure contain also phosphoric acid and potash. Allowance was of course made for their percentages of these two constituents. Equivalent amounts of the several fertilizers were used. Potash and phosphoric acid (full doses) were the constants.

The full dose of nitrogen in the several organic manures gave results as follows:

	Pounds.
Stable manure	392
Dried blood	358
Cotton-seed meal	312
Cotton seed (ground)	286
Cotton seed (whole)	275

The stable manure gave the best combined average and the dried blood the next best. Cotton-seed meal and cotton seed gave very nearly the same averages. The whole cotton seed gave just as good results as the ground.

The full doses of nitrogen in the inorganic, mixed, and organic forms may be compared by taking as the representative of the latter the average of the five organic manures mentioned above:

	Pounds.
Mixed nitrogen	395
Organic nitrogen	325
Inorganic nitrogen	318

The mixed nitrogen, as stated above, was furnished by stable manure and nitrate of soda, the inorganic nitrogen by nitrate of soda. This comparison favors the mixed nitrogen, and makes the other two forms show practically the same combined averages. By referring to the averages of the organic manures given above it will be seen, however, that in one kind (stable manure) organic nitrogen gave just the same results as the mixed nitrogen, and in another (dried blood) better results than inorganic nitrogen; also that in the other three kinds (cotton-seed meal, ground cotton seed, and whole cotton seed) it was about as effective as the inorganic form. It is clear that the stable manure largely affected the foregoing comparisons. Wherever used its effects were pronounced, and increasingly so from year to year. Six tons of stable manure and 3 tons of stable manure mixed with 160 pounds of nitrate of soda, both furnishing the full dose of nitrogen (together with full doses of potash and phosphoric acid), applied annually upon the same plats, greatly improved their physical properties, as will appear from the following comparisons of averages for 1888 and 1890:

At the upper farm the stable manure averaged 236 pounds for 1888 and 387 pounds for 1890; at the lower farm, 377 pounds for 1888 and 536 pounds for 1890. The mixture of stable manure and nitrate of soda gave at the upper farm 203 pounds in 1888 and 454 pounds in 1890; at the lower, 376 pounds in 1888 and 525 pounds in 1890. Its cumulative effects were marked. It is often impossible, however, for the farmer to get a sufficiency of stable manure for his entire crop. That a part of it can be fully replaced by some other nitrogenous fertilizer clearly appears from the following: Six tons of stable manure gave 392 pounds of lint per acre; 3 tons of stable manure and 160 pounds nitrate of soda, 395 pounds.

It is evident that 160 pounds of nitrate of soda were fully equal in its effects to 3 tons of stable manure. For similar reasons to those given under the last head, half doses of nitrogen were also tested, with the following results:

	Pounds.
Dried blood	364
Cotton-seed meal	343
Ground cotton seed	279
Nitrate of soda	269

The dried blood maintained its superiority. The cotton-seed meal showed somewhat better results than the ground cotton seed and nitrate of soda, which gave about the same combined averages.

Leaving out the stable manure, and in the comparison of the remaining nitrogenous fertilizers averaging the results of the full and half doses of each kind (taking it as fully established that the two doses were equally effective), their results may be finally shown as follows:

	Pounds.
Dried blood	361
Cotton-seed meal	327
Ground cotton seed	283
Nitrate of soda	293

The dried blood showed the best average results and the cotton-seed meal the next best. The ground cotton seed and nitrate of soda gave about the same averages.

It appears from the results of the tests of this series that organic nitrogen gave better results than inorganic; that of the several organic fertilizers stable manure was the best and dried blood the next best, that the difference between the cotton-seed meal and cotton seed was slight, but in favor of the meal, and that there was no difference between the ground and whole cotton seed; also that the inorganic form, in nitrate of soda, was equally as effective as the organic form in cotton seed.

The comparative effects of the full and half doses of nitrogen in the different kinds of nitrogenous manures were referred to in discussing the results of the preceding series. They may be given a little more fully here.

Combined average yield of lint per acre on the two farms for three years.

	Dried blood.	Cotton-seed meal.	Ground cotton seed.	Nitrate of soda.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Full dose	358	312	286	318
Half dose	364	343	279	269

The probable error must be allowed for. There can be no question of the equal efficacy of the half dose as compared with the full. The results strengthen the conclusions drawn from those of the preceding series, to the effect that the half, as well as the full, dose of nitrogen was excessive, and the true amount required is to be found somewhere between the quarter and half dose.

CALCAREOUS MANURES.

Although it is now held that it is only necessary to return to the soil nitrogen, phosphoric acid, and potash, yet a soil may sometimes be deficient in lime, and hence need calcareous manures. Again, some plants require considerable percentages of lime. In order to ascertain whether cotton on the soils of our farms would respond to applications of lime, and also to check our series of tests of phosphatic fertilizers, as explained above, a number of experiments were carried on at both farms, alongside of those of this series. Abundant deposits of marl, a highly calcareous manure, are found in different parts of the South. Hence it was preferred for our tests. The kind used was finely ground and contained 55.4 per cent of lime, together with 2.9 per cent phosphoric acid and a trace of potash. The dose of lime required by a crop of cotton giving 300 pounds of lint per acre is, according to the old analyses, 60 pounds. This amount was furnished by 110 pounds of marl. It was added to the full doses of nitrogen, phosphoric acid, and potash, with the following results:

	Pounds.
1 potash, 1 phosphoric acid, and 1 nitrogen	318
1 potash, 1 phosphoric acid, 1 nitrogen, and 1 lime	250

In these and several other tests made at one or other farms the marl failed to show any beneficial effect upon the crop.

It was stated that the marl contained a small percentage (2.9 per cent) of phosphoric acid. While in the number of pounds required to furnish the full or double dose of lime the amount of phosphoric acid would be insignificant, 450 pounds of marl would furnish 13 pounds of phosphoric acid or half the theoretical amount required, and 900 pounds would furnish the full dose. The phosphoric acid in marl is insoluble. In order to supplement the preceding series of experiments with phosphatic manures, by testing more fully the effects of the insoluble phosphoric acid in combination with other fertilizers and when used alone, 450 pounds of marl per acre were used at the upper farm in combination with full doses of potash, phosphoric acid (in acid phosphate), and nitrogen (in cotton-seed meal), and 900 pounds per acre were applied alone at both farms. On the upper farm the results were as follows:

Average yield of lint per acre at the upper farm for three years.

	1888.	1889.	1890.	Three years.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1 potash, 1 phosphoric acid, 1 nitrogen	276	352	307	312
Same, with addition of 450 pounds of marl	261	341	295	299

The two applications gave about the same returns. The average yields on the two farms for three years in pounds of lint per acre were as follows:

	Pounds.
Unfertilized	85
1 phosphoric acid and 8 lime (in 900 pounds of marl)	94
1 phosphoric acid (in acid phosphate)	159

The marl, containing eight times the amount of lime required by the given crop, as well as the full dose of phosphoric acid in the insoluble form, gave about the same combined average as the unfertilized plats, and much poorer returns than the full dose of soluble phosphoric acid in acid phosphate.

It appears, therefore, from the results of these tests, as well as from those of the preceding series, that insoluble phosphoric acid, whether supplied by basic slag, floats, or marl, is inferior to the soluble phosphoric acid in the acid phosphate, and of little value to cotton.

In all the foregoing tests, with a single exception, the marl was of no benefit to the crop. In the exception referred to, its beneficial effects were probably due to its action upon the organic matters of the soil. This will more clearly appear from the results of the following tests made at the lower farm. In 1888 two plats (duplicates) were dressed with 900 pounds marl each and planted in cotton. Cowpeas were drilled in between the rows at the last working given the cotton. In the fall, after the cotton was picked out, the plats were seeded in oats. In the spring of 1889 the oats were turned under, and peas were again planted without manures of any kind. In the fall the peas were plowed under and the plats were seeded in oats. In the spring of 1890 the oats were turned under and the plats were again dressed with 900 pounds of marl and put back in cotton. It is well known that calcareous manures act beneficially upon leguminous crops, such as peas, clover, etc. It was expected of this test, first, that the heavy dressing of marl would greatly improve the several crops of peas and, therefore, aid in supplying a large amount of vegetable matter to the soil and at the same time hasten its decomposition; and second, that this vegetable matter would, in its turn, cheaply furnish nitrogen to the cotton crop, and improve the physical properties of the soil. It will be noticed that marl was the only fertilizer used, that the plats were in peas without cotton in 1889 and unmanured, and that when planted in cotton in 1888 and 1890 each received 900 pounds of marl per acre. It will be interesting to compare the results with some already noticed.

Average yields of lint per acre at the lower farm in 1890.

	Pounds.
Unfertilized (in cotton in 1888 and 1889, unfertilized each year)....	86
900 pounds of marl (in cotton in 1888 and 1889, with 900 pounds marl each year)........	71
Full doses of nitrogen, phosphoric acid, and potash (1888 and 1889—same crop and fertilizers)........	392
900 pounds of marl (1888 cotton with 900 pounds marl; 1889 peas only unfertilized)	364

The figures are surprising. While the marl used alone was clearly of no value to the cotton, in connection with the vegetable matter of the peas and oats it increased the yield more than tenfold, and gave returns nearly equal to those of the full doses of nitrogen, phosphoric acid, and potash.

The tests of this series go to show that lime in marl, whether used n small or large doses, is of little value to cotton in the absence of organic matter, but that where this is present it acts beneficially; also that it can be used with decided advantage upon the pea crop.

EFFECTS OF COPPERAS.

Articles have been repeatedly published in Southern agricultural journals asserting that copperas would prevent the rusting of cotton. Such claims are opposed to the opinion generally held that sulphate of iron (copperas) acts injuriously in the soil. In order to test them, different amounts of copperas were applied each year with full doses of nitrogen, phosphoric acid, and potash, with the following results:

	Pounds.
Without copperas	318
With 100 pounds of copperas	283
With 50 pounds of copperas	307

It is evident the copperas produced no effect, either beneficial or injurious, upon the crop.

THE BEST TIME FOR APPLYING NITRATE OF SODA.

There is considerable difference of opinion as to the best time for applying nitrate of soda. It can, of course, be most economically applied with the other fertilizers at the time of planting. It is objected to this, that there is danger of the nitrate being washed out of the soil by heavy spring rains before the crop is sufficiently advanced to assimilate it. Others hold that it can be more effectively applied in one or more top-dressings. A number of experiments bearing upon this question were begun at the lower farm in 1889. The full doses of potash and phosphoric acid were in every case used with the nitrate of soda. Nitrate of soda containing the full dose of nitrogen was applied at different times, as follows: All at time of planting; half at planting and half in one top-dressing; all in one top-dressing; all in two equal top-dressings. From the results of the tests it appeared that nitrate of soda can be applied as effectively, and certainly more economically, with the other fertilizers at the time of planting, as it can in one or more top-dressings.

METHODS OF APPLYING FERTILIZERS.

In the South the fertilizers used on cotton are generally applied in the hill or drill before or at the time of planting. Whether drilling will, under all circumstances, give better results than broadcasting is a question not yet decided. Our tests bore upon it. Applications containing both the full and half doses of nitrogen, with full doses of potash and phosphoric acid, were tested at both farms. The nitrogen was furnished by cotton-seed meal. The applications containing the full dose gave results as follows:

	Pounds.
In hill	312
Broadcast	303

It is evident that the two applications gave about the same results.

The applications containing the half dose of nitrogen gave results as follows:

	Pounds.
In hill	343
Broadcast	245

The difference in favor of drilling amounted to about 100 pounds of lint per acre at each farm.

Other combinations of fertilizers were tested in the same way at the lower farm. The results showed that where liberal amounts of fertilizers were used one method was certainly as effective as the other, but where smaller amounts were employed the tests appeared to favor drilling.

THEORETICAL AND ACTUAL YIELD OF LINT PER ACRE.

It has been explained that our applications, when full doses were used, supplied the amount of potash, phosphoric acid, and nitrogen contained in a crop of cotton yielding 300 pounds of lint per acre. According to the old analyses and determinations, which we were obliged to fall back upon, this crop is made up as follows: Lint 300 pounds, seed 600 pounds, leaves 500 pounds, bolls 500 pounds, stems 1,200 pounds, roots 300 pounds; total 3,400 pounds, containing 52 pounds of nitrogen, 48 pounds of potash, and 26 pounds, of phosphoric acid. Determinations and analyses made by our assistant chemist, J. B. McBryde, continued for two years and carefully duplicated and checked each season, showed the above figures to be inaccurate, and that the crop is made up of 300 pounds of lint, 654 pounds of seed, 404 pounds of leaves, 575 pounds of bolls, 658 pounds of stems, and 250 pounds of roots; total 2,841 pounds, containing 46 pounds of nitrogen, 39 pounds of potash, and 12 pounds of phosphoric acid. The two series differ widely in their amounts of stems and phosphoric acid. In other respects, the agreement between them is reasonably close.

The table giving the results of our analyses and determinations is of such value in the present connection as to call for its insertion here. It was first given to the public in a bulletin of the experiment station of the University of Tennessee entitled A Chemical Study of the Cotton Plant.

Fertilizing constituents contained in a crop of cotton yielding 300 pounds of lint per acre.

Fertilizing constituents (calculated).	Pounds per acre.						
	In 300 pounds lint.	In 654 pounds seed.	In 404 pounds bolls.	In 575 pounds leaves.	In 658 pounds stems.	In 250 pounds roots.	In 2,841 pounds total crop.
Nitrogen	0.72	20.08	4.60	13.85	5.17	1.62	45.94
Phosphoric acid, P_2O_5	0.18	6.60	1.14	2.57	1.22	0.38	12.15
Potash, K_2O	2.22	7.63	12.20	6.57	7.74	2.75	39.11
Soda, Na_2O	0.08	0.12	0.19	1.61	0.65	0.38	3.03
Lime, CaO	0.40	1.22	3.75	31.57	5.59	1.36	43.95
Magnesia, MgO	0.41	3.26	1.01	5.73	2.43	0.80	13.64
Sulphuric acid, SO_3	0.26	0.84	1.75	3.38	0.74	0.28	7.25
Insoluble matter	0.08	0.15	1.14	6.43	0.89	0.55	9.24

Confining our attention for the present to the old analyses, it will be of interest to inquire as to the correspondence between the expected and actual results of the applications. As already stated, after examining the soils of the two farms and inquiring into their history, we assumed that they would produce, without manures of any kind, about 50 pounds of lint per acre. It will be seen from the figures that they gave somewhat better results than this, their average produce of lint for the three years amounting to 74 pounds at the upper farm and 96 pounds at the lower, or an average of 85 pounds for the two farms. The full applications furnished amounts of the three constituents sufficient, theoretically, to produce 300 pounds of lint per acre. Hence, the crops should have averaged for the three years 374 pounds of lint at the upper farm and 396 pounds at the lower, or 385 pounds for the two farms.

It will be remembered that mixed nitrogen in stable manures and nitrate of soda, and organic nitrogen in stable manure, and dried blood, gave the best averages. Their results may be compared with the above figures as follows:

	Pounds.
Expected crop	385
Stable manure and nitrate of soda	395
Stable manure	392
Dried blood	385

Two of the applications actually gave the expected averages at both farms, and the third gave it at the lower.

It has already been observed that either increasing the amount of nitrogen or potash by as much as 100 per cent or decreasing it by 50 per cent was without effect upon the crop, but that it quickly responded to any change in the soluble phosphoric acid. By way of additional confirmation of this statement, and in order to show the difference between the expected and actual results of the several applications of commercial fertilizers, it may be well to submit a few more comparisons. Excluding, therefore, the stable manure and cotton seed, the average of the applications containing the full doses of the three constituents (the phosphoric acid in soluble form), the average of those containing half doses of potash or nitrogen together with full doses of the other constituent and of soluble phosphoric acid, and the averages of those containing double doses of potash or nitrogen, together with the full dose of soluble phosphoric acid and the full or double dose of the other constituent, may be compared as follows:

	Pounds.
Expected crop	385
Average of full dose of three constituents	328
Average half dose of nitrogen or potash	316
Average of double doses of nitrogen or potash or both	289

It will be noticed that the three averages fell considerably below the expected or theoretical crop.

The average of the several applications containing double doses of soluble phosphoric acid, together with full doses of the other two constituents, or the full dose of one and double dose of the other, corresponded almost exactly, on the other hand, with the theoretical average, as appears from the following:

	Pounds.
Expected crop	385
Average of double dose of soluble phosphoric acid	386

The agreement between the combined averages is perfect.

It is known that fertilizers produce their full effects only in good seasons. The tests showed that 1889 was the most favorable of the three seasons at the upper farm, and 1890 the most favorable at the lower farm. It may be asked, How would the comparisons of the actual and expected results stand for those years? It is noteworthy that the unfertilized plats averaged 86 pounds of lint per acre at the upper farm in 1889, and the same number of pounds at the lower in 1890. The several applications were therefore expected to show 386 pounds of lint per acre at each farm for the years named. Comparing with this five of the applications containing full doses of nitrogen, phosphoric acid, and potash, we have:

Average yields of lint per acre on two farms.

	Upper farm, 1889.	Lower farm, 1890.
	Pounds.	*Pounds.*
Expected crop	386	386
Dried blood	366	410
Nitrate of soda	348	392
Cotton-seed meal	352	355
Kainit	371	406
Sulphate of potash	360	375

Whether we consider the correspondence between the assumed and actual yields, between the results of the same applications at the two farms, or between the results of the several applications at each farm, the agreement in the figures is surprising—closer could not be expected in work of this kind. In no case does the difference exceed the probable error.

CONCLUSIONS.

Carefully studied in all their bearings the results of our tests of fertilizers warrant the following general conclusions:

(1) Cotton requires nitrogen, phosphoric acid, and potash.

(2) Of the three, phosphoric acid is relatively the most important and controls the action of the other two. It can be used alone with some advantage to the crop, but much more effectively in connection with potash and nitrogen.

(3) Nitrogen is relatively more important than potash. It can only be advantageously used in combination with phosphoric acid, or phosphoric acid and potash.

(4) Potash, like nitrogen, is of little value to cotton when applied separately; it must be combined with the other constituents.

(5) Expressed in terms of the old analyses the proportion and amounts of nitrogen, phosphoric acid, and potash required, are as follows:

Between one fourth and one half nitrogen, about 2 phosphoric acid, between one fourth and two fifths potash.

Or, stated in terms of our later and corrected analyses:

Between three sevenths and four sevenths nitrogen, about 4¼ phosphoric acid, between one third and one half potash.

With proper allowance for the cost as well as the effect of each application, the requirements may be more exactly given as follows: 0.43 nitrogen, 4.16 phosphoric acid, 0.38 potash. In other words, the required proportion is, 1 nitrogen, 2½ phosphoric acid, and ¾ potash, and the amounts called for by a crop yielding 300 pounds of lint per acre are, nitrogen 20 pounds, phosphoric acid 50 pounds, and potash 15 pounds.

(6) The amount of phosphoric acid determines the amount of nitrogen and potash; with a given amount of the first, only certain amounts of the last two can be profitably used.

(7) The amount of phosphoric acid and proportionate amounts of nitrogen and potash can not be indefinitely increased with the expectation of obtaining a corresponding increase in the crop. The gain in crop does not keep pace with increase of fertilizers, and a point is speedily reached beyond which this gain is not sufficient to meet the additional cost of the heavier applications. The soil can not be profitably forced; the application of fertilizers must be regulated by its mechanical as well as chemical condition.

(8) Potash can be as effectively supplied by muriate of potash or kainit as it can by sulphate of potash. This is opposed to the view which regards the chlorides of the two former as injurious, and therefore holds that the higher priced potash of the latter is to be preferred. Since equivalent amounts of potash in the three kinds are of equal value to cotton, the choice of the farmer must be determined by their relative cost. At present prices, and especially when the matter of freight is considered, the potash of the muriate is the cheapest.

(9) Phosphoric acid is of value to cotton in proportion to its solubility; hence the several kinds of phosphatic manures can not be indifferently employed. Preference must be given to acid phosphates containing considerable percentages of soluble phosphoric acid. Insoluble phosphoric acid in slag, floats, or marl is of little direct value to the crop upon which it is applied, and even granting that its effects in the soil may be lasting, they are not, in the long run, sufficiently pronounced to meet the interest on the capital invested in the application. Speculating in futures is not a safe business. According to the best agricultural experience of our day, the better plan is to use only such fertilizers as will meet the demands of the crop upon which they are applied.

(10) Inorganic, organic, and mixed nitrogen are of very nearly equal value to cotton. The slight difference is in favor of the last two. Stable manure, containing organic nitrogen is the best fertilizer of its class, and is lasting or cumulative in its effects. The organic nitrogen of stable manure to the amount of 50 per cent can be fully replaced by the inorganic nitrogen of nitrate of soda.

Of the commercial forms of nitrogen, among which the farmer has to choose, the organic nitrogen of dried blood is perhaps the best, and at present prices the cheapest. As between cotton-seed meal and cotton seed there is a slight difference in favor of the former. Whole cotton seed is as efficacious as ground cotton seed. Inorganic nitrogen in nitrate of soda is about as valuable to cotton as organic nitrogen in cotton seed or cotton-seed meal.

(11) Used alone or in combination with commercial fertilizers the lime of marl is of no direct value to cotton. Mixed with acid phosphate it may even act injuriously by retarding or preventing its solution in the soils. Applied upon leguminous crops, such as cowpeas, vetch, etc., which are to be turned under as a preparation for cotton, its indirect value is great.

(12) Applications of copperas are without effect upon cotton.

(13) Nitrate of soda should generally be applied with the other fertilizers at the time of planting.

(14) Fertilizers may be indifferently drilled or broadcasted where they are liberally applied, but drilling is to be preferred where small amounts are employed.

(15) The foregoing conclusions of course apply only to soils similar in character and condition to those tested at our two farms. Of these the lower was light and sandy; the upper contained a considerable percentage of clay. Both were quite thin. They fairly represented, therefore, large and different classes of Southern soils. When it is also stated that the seasons of the three years varied greatly and that the results of the corresponding tests closely agreed at the two farms, it follows that the conclusions admit of fairly wide application.

PRACTICAL APPLICATIONS.

It may be asked by the farmer, How can the required amounts of nitrogen, phosphoric acid, and potash be supplied? Suppose the choice of materials to be limited—that only cotton seed, kainit, or stable manure can be obtained. The following tabular statements will furnish useful guidance in the work of preparing composts or mixing fertilizers. The first gives the average percentages of nitrogen, phosphoric acid, and potash in different fertilizing materials.

Average percentages of nitrogen, phosphoric acid, and potash in different fertilizers.

Fertilizer.	Nitrogen.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*	*Per cent.*
Sulphate of ammonia	20.50		
Nitrate of soda	15.75		
Dried blood	12.00		
Cotton-seed meal	7.00	2.75	1.75
Cotton seed	2.50	1.30	1.20
Stable manure	0.45	0.25	0.40
Dissolved boneblack		18.00	
Acid phosphate		15.00	
Basic slag		21.50	
Floats		26.50	
Acid phosphate (with potash)		13.50	1.75
Cotton-seed hull ashes		9.00	22.50
Wood ashes		1.75	6.00
Muriate of potash			50.00
Sulphate of potash			37.00
Kainit			12.00

The figures represent, in each case, the averages of many analyses. Suppose it is wished to use nitrate of soda. It contains, according to the tabular statement, 15¾ per cent of nitrogen, and it will be found, by a very simple calculation, that 127 pounds will furnish the required dose of nitrogen, 20 pounds. If cotton-seed meal is preferred, a similar calculation will show that 285 pounds will give the required amount of nitrogen, and also 7.8 pounds of phosphoric acid and 4.9 pounds of potash. According to the above percentages the remainder of the phosphoric acid and potash required can be supplied by 281 pounds of acid phosphate and 92 pounds of kainit.

The number of pounds of nitrogen, phosphoric acid, and potash required by a crop of cotton yielding 300 pounds of lint per acre, are supplied by each of the following formulas:

Formulas required by cotton.

1	Muriate of potash	pounds..	30
	Acid phosphate (16 per cent of phosphoric acid)	do....	312
	Nitrate of soda (16 per cent of nitrogen)	do....	125
2	Muriate of potash	do....	30
	Acid phosphate (15 per cent of phosphoric acid)	do....	334
	Dried blood	do....	167
3	Muriate of potash	do....	20
	Acid phosphate (15 per cent of phosphoric acid)	do....	281
	Cotton-seed meal	do....	286
4	Muriate of potash	do....	10
	Acid phosphate (with potash)	do....	312
	Cotton-seed meal	do....	286
5	Cotton-seed hull ashes	do....	45
	Acid, phosphate (15 per cent of phosphoric acid)	do....	261
	Cotton-seed meal	do....	286
6	Wood ashes (unleached)	do....	167
	Acid phosphate (15 per cent of phosphoric acid)	do....	261
	Cotton-seed meal	do....	286
7	Kainit	do....	58
	Acid phosphate (15 per cent of phosphoric acid)	do....	300
	Nitrate of soda	do....	70
	Stable manure	ton..	1
8	Muriate of potash	pounds..	20
	Acid phosphate (15 per cent of phosphoric acid)	do....	300
	Nitrate of soda	do....	64
	Cotton seed	bushels..	23⅛
9	Kainit	pounds..	64
	Acid phosphate (15 per cent of phosphoric acid)	do....	273
	Cotton-seed meal	do....	143
	Cotton seed	bushels..	13½
10	Kainit	pounds..	45
	Acid phosphate (15 per cent of phosphoric acid)	do....	264
	Cotton seed	bushels..	26½
11	Acid phosphate (15 per cent of phosphoric acid)	pounds..	266
	Nitrate of soda	do....	13
	Stable manure	tons..	2
12	Ammoniated acid phosphate with potash, containing, nitrogen, 4 per cent (equal to 4.85 per cent ammonia); phosphoric acid, 10 per cent (nearly all available); and potash, 3 per cent	pounds..	500

No. 1 is the formula used in our tests. The materials cost about $4.50. Where commercial fertilizers are employed No. 2 will give the best results. Cost, about $4.25.

When dried blood can not be obtained it can be replaced by cotton-seed meal, as in No. 3. Cost, about $4.70.

According to the late reports of State chemists, the acid phosphates offered for sale in our markets contain, on the average, 15 per cent of total phosphoric acid. There is, unfortunately, some confusion in the nomenclature of the phosphates. The term *acid phosphate* is applied by some manufacturers to dissolved phosphatic rock containing small percentages of potash. Without the potash the fertilizer is indifferently called dissolved bones, superphosphate of lime, acidulated rock, etc. At the North the last kinds are called plain superphosphates, or acid phosphates—a better term.

It is sometimes difficult to get the plain acid phosphate—that is, an acid phosphate without potash. In this case No. 4 should be used.

In the neighborhood of the oil mills cotton-seed hull ashes can often be bought at moderate prices and may be advantageously substituted, as in No. 5, for the muriate of potash in No. 3. Cost, about $4.75.

When the wood ashes of the household fires are carefully saved, they may in turn replace the cotton-seed hull ashes, as in No. 6, and reduce the cost to $4.30.

In No. 7 half the required amount of nitrogen is furnished by nitrate of soda and half by stable manure, and the potash chiefly by kainit. It will be remembered that mixed nitrogen gave excellent results. The materials, exclusive of the stable manure, will cost about $3.25.

In No. 8 the potash is supplied by muriate of potash, and the stable manure is replaced by cotton seed. The cost, exclusive of the cotton seed, is about $3.05.

In No. 9 kainit replaces the muriate of potash in No. 8, and cotton-seed meal the nitrate of soda. Cost, exclusive of the cotton seed, about $3.25.

No. 10 may be used when there is an abundance of cotton seed. Excluding the cotton seed, the other materials will cost about $1.70.

If, on the other hand, the supply of stable manure is abundant, No. 11 may be used with advantage. The materials, exclusive of the stable manure, will cost about $1.70.

If it is desired to use a manufactured article, one containing the percentages of No. 12 should be ordered.

FARMERS' BULLETINS.

Applications for bulletins of this series should be addressed to the Secretary of Agriculture, Washington, D. C.

[Farmers' Bulletins Nos. 1, 2, 4, 5, 8, 10, and 13 are not available.]

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. Pp. 24. Issued March, 1891.

Farmers' Bulletin No. 6. Tobacco: Instructions for its Cultivation and Curing. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 7. Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in its Relation to the Public Health. Pp. 20. Issued April, 1892.

Farmers' Bulletin No. 9. Milk Fermentations and their Relations to Dairying. Pp. 24. Issued July, 1892.

Farmers' Bulletin No. 11. The Rape Plant: Its History, Culture, and Uses. Pp. 20. Issued June, 1893.

Farmers' Bulletin No. 12. Nostrums for Increasing the Yield of Butter. Pp. 16. Issued June, 1893.

Farmers' Bulletin No. 14. Fertilizers for Cotton. Pp. 32. Issued March, 1894.

Farmers' Bulletin No. 15. Some Destructive Potato Diseases: What They Are and How to Prevent them. Pp. 8. Issued April, 1894.

Farmers' Bulletin No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24. Issued April, 1894.

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Farmers' Bulletin No. 19. Important Insecticides: Directions for their Preparation and Use. Pp. 20. Issued July, 1894.

Farmers' Bulletin No. 20. Washed Soils: How to Prevent and Reclaim Them. Pp. 22. Issued November 30, 1894.

Farmers' Bulletin No. 21. Barnyard Manure. Pp. 32. Issued November 19, 1894.

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Farmers' Bulletin No. 23. Foods: Nutritive Value and Cost. Pp. 32. Issued January 21, 1895.

Farmers' Bulletin No. 24. Hog Cholera and Swine Plague. Pp. 16. Issued December 12, 1894.

Farmers' Bulletin No. 25. Peanuts: Culture and Uses. Pp. 24. Issued February 9, 1895.

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