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SUMMARY

The different soil types of the sugar-cane district of Louisiana vary somewhat in their response to applications of nitrogen and phosphoric acid, applied in the forms of cyanamid, ammonium phosphate 11-48-0, and superphosphate.

On Mississippi Alluvium, First-Bottom Soils, whose fertility had been built up by rotation, cultivation, and incorporation of organic matter over a period of years, plant cane did not respond to fertilizer treatments. On run-down soils of this type, plant cane responded profitably to fertilization both with nitrogen and phosphoric acid. First- and second-year stubble gave marked response to applications of 200 to 300 pounds of cyanamid per acre.

On Coastal Prairie Sedimentary Soils, plant cane gave very profitable increases from the use both of nitrogen and phosphoric acid. First-year stubble responded profitably to 200 pounds of cyanamid with 200 pounds of superphosphate.

On Mississippi-Red River Sedimentary Soils, plant cane produced profitable increases from the use of 100 pounds of cyanamid; first-year stubble cane to from 200 to 300 pounds of cyanamid; and second-year stubble to 300 pounds of cyanamid. In some cases definite need for phosphoric acid was shown.

First-year stubble, in most instances, showed residual effects from fertilizer applied to plant cane.

Two time-of-application tests with plant cane on Mississippi Alluvium, First-Bottom Soils indicated that applications of cyanamid in the fall, before planting, gave no material gains over spring applications. The intermediate date, around April 18, was found to be the most advantageous time to apply cyanamid.
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ALLEN K. SMITH, JR.

Calcium cyanamid is one of the oldest air-nitrogen fertilizers. It is the only one produced directly by a synthetic process. Other processes first produce ammonia or oxides of nitrogen which must later be combined with suitable carriers. Calcium cyanamid also has the advantage of being the only nitrogenous fertilizer that contains excess lime.

The cyanamid* produced in America contains 22 per cent nitrogen and 70 per cent hydrated lime equivalent. It is marketed in two forms: granular and pulverized. The granular form is a dust-free product which passes a 12-mesh screen. The pulverized form—the one used in the experiments reported in this bulletin—is oiled to prevent undue dustiness. Both forms are grayish-black in color due to the presence of a small quantity of inert carbon.

Cyanamid is used as a source of nitrogen, as a soil corrective, and as a conditioner in the production of mixed fertilizers. For direct application to the soil, it is finding wide use in the fertilization of such crops as sugar cane and corn.

It has been definitely shown (See "Review of Literature" in back of this bulletin) that cyanamid is a satisfactory fertilizer for sugar cane, and that it produces very profitable returns when applied to stubble cane. Under certain conditions it may also be applied to advantage to plant cane. It has been used in quantity in the Louisiana cane belt for a number of years. With this in mind, the study reported herewith was undertaken.†

OBJECT OF STUDY

The object of this study was to determine systematically the following points on the use of cyanamid as a source of nitrogen when applied to the various sugar-cane soils and under the climatic conditions obtained in Louisiana:

1. Effectiveness of cyanamid with and without phosphoric acid.
2. Rate at which cyanamid should be applied for best results.
3. Time of application of cyanamid.
4. Residual effects of cyanamid with and without superphosphate.

* For purposes of brevity the term cyanamid (final e omitted) will be employed for the commercial product. Ordinarily this contains, as manufactured, about 63 per cent calcium cyanamide, 15 per cent free hydrated lime, 12 per cent carbon, 5 per cent limestone impurities and 5 per cent oil. In the case of granular cyanamid, calcium nitrate is substituted for the oil.

† This study, covering a three-year period, was made under an industrial Fellowship established at the Louisiana State University, February 1, 1930, by the American Cyanamid Company of New York. The work was done under the direction of Mr. W. G. Taggart to whom the author is indebted for many helpful suggestions.
SUGAR-CANE SOILS OF LOUISIANA

The soils of the sugar-cane district of Louisiana are practically all alluvial in origin. Many years ago, before the present levee systems were built, the Mississippi River and its tributaries flooded this section periodically. Each time, vast quantities of sediment were carried along and deposited, the heavier and coarser material near the watercourses
and the silt and clay in the lower levels away from the main channels. The deposits differ from place to place, because the alluvium brought down by the rivers was not always drawn from the same part of the country, and because the floods were sometimes local, affecting only a few square miles.

The soils of the sugar-cane district are divided into five major types:

1. Mississippi Alluvium, First-Bottom Soils.
5. Coastal Prairie Sediments of the Gulf Coastal Plain.

Most of the sugar-cane district falls under the first major division, and it is on this soil type that the majority of the fertilizer test plots were located. Some were located on the Mississippi-Red River Sedimentary Soils and on the Coastal Prairie Sedimentary Soils.

Since varying responses to fertilizers were obtained from the different soil types, the "Discussion of Results" is divided according to the soil type on which each test was located. The averages in Tables 1, 2, and 3 show the range of response to fertilizers under the several conditions, and should approach the averages under plantation conditions.

PLAN AND PROCEDURE

A series of plot tests was replicated two or three times at eight or ten different locations in the state, and included several soil types.

In conducting the plot tests on plant cane the following standard outline was used wherever conditions were favorable, with the intention of continuing the program on the stubble crops.
In some cases it was necessary to use a modified outline—i.e., instance the following standard outline for plot 2, and again without plot 6. In 1932, the plant-cane tests included rate studies, time-of-application studies, and a comparison of cyanamide alone against cyanamide and superphosphate, in conjunction with a rate study.

### STANDARD OUTLINE USED IN MAKING TESTS REPORTED IN THIS BULLETIN

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Plant Cane Application</th>
<th>First-Year Stubble Application</th>
<th>Second-Year Stubble Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acre</td>
<td>Pounds</td>
<td>Material</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>200</td>
<td>Cyanamid   Superphosphate</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>200</td>
<td>Cyanamid   Superphosphate</td>
</tr>
<tr>
<td>3</td>
<td>Check-No fertilizer</td>
<td>200</td>
<td>Cyanamid</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>300</td>
<td>Cyanamid</td>
</tr>
<tr>
<td>5</td>
<td>Ammonium phosphate 11-48-0</td>
<td>300</td>
<td>Cyanamid</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>300</td>
<td>Superphosphate</td>
</tr>
</tbody>
</table>
The stubble tests were mostly rate studies, with and without the supplemental use of superphosphate. There were also rate studies and time-of-application tests on first-year stubble with cyanamid as the only fertilizer.

Each spring of the three years during which this work was conducted, the fertilizer test fields were located with the following points in mind:

1. Type of soil.
2. Uniformity of conditions.
3. Fertility of soil.
4. Variety of cane.
5. Regularity of stand.
6. Location of field with reference to mill or loading derrick.
7. Cooperative qualities of owners and managers.

Where possible, the plots were at least a half acre in size, most of them ranging from one to two acres. Large plots were used because in many cases the cane was shipped in railroad cars and it was desirable to have enough produced on each plot to fill a car.

All fertilizer was applied with Avery distributors, used generally throughout the cane territory.

The fertilizer was applied over the loose dirt near the off-bar furrow, so that this dirt was mixed with the fertilizer when it was thrown back to the cane. Where the fertilizer was applied ahead of planting the crop, it was placed directly in the furrow and mixed with the soil by a heavy chain attached to the rear of the distributor.

Observations were made and notes were kept during the growing season to aid in interpreting the data secured after the cane was harvested and milled.

The cutting, hauling, and milling of the cane from each plot was done under the personal supervision of the author. The cane was weighed on the scales regularly used by the cooperators.

Whenever possible, all the cane produced from a plot was milled, and a composite sample taken by frequent dipping of small quantities of juice as the cane was crushed. Where it was impractical to do this, the juice from about 6 tons of cane taken from different parts of the plot were used to make up the sample.

All analyses of juice were made by chemists at the mill where the cane was ground. The normal juice (which was used throughout in determining acre yields of sugar) was computed from the crusher juice by the chemist who analyzed the samples, using his own mill factor.
In order to have a uniform set of "96°-sugar-per-acre" figures, a boiler-house efficiency of 100 per cent and an extraction of 75 per cent were used along with the Winter-Carp formula, shown below.

\[
X = \frac{40}{S} \times (1.4 - C) \times 100
\]

where \(X\) = Pounds of 96 per cent sugar per ton of cane.
\(S\) = Per cent sucrose in juice in terms of weight of cane.
\(C\) = Coefficient of purity of juice.

The value of the cane was computed by giving a value of $0.035 to each pound of sugar produced. This value is approximately the average of the three years during which this work was conducted.

In determining the net value of the cane produced, or the profit or loss per acre, an average of the three years' (1930, 1931 and 1932) prices of the several fertilizer materials was employed.

The average price of cyanamid amounted to $36.20 per ton, or $1.81 per application of 100 pounds (supplying 22 pounds of nitrogen). That of ammonium phosphate 11-48-0 was $53.30 per ton, or $5.33 for an application of 200 pounds (supplying 22 pounds of nitrogen and 96 pounds of P\(_2\)O\(_5\)). Superphosphate averaged $20 per ton, or $2.00 per application of 200 pounds (supplying 32 pounds of P\(_2\)O\(_5\)).

The cost per acre of applying fertilizer to sugar cane was determined by assuming that one man and a team could handle 12 acres in one day. Assuming again that the daily wage of the man is $1.00, that of feeding and keeping a team of mules is $1.40 per day, then the cost of an application of fertilizer, in addition to the actual cost of the fertilizer material, would be $.20 per acre. This figure would vary only slightly as the rate of fertilizer applied per acre increased, so the nominal figure of $.20 per application per acre was used throughout in determining the cost of applying fertilizer.

Where unfertilized check plots were used, a charge of $1.00 per ton was made against the fertilized plots, in addition to the charge made for the fertilizer and the application, to cover the cost of cutting and hauling the increases in tonnage resulting from the use of fertilizer.

Actual profit could not be calculated where no unfertilized check plots were used. Instead, a value of the sugar produced per acre was determined by using the average price of $.035 per pound mentioned before. From the "value cane per acre" was taken the cost of the fertilizer materials and the cost of application. In this way the "value cane less cost of fertilizer" was obtained. (See tables). The comparisons made were between the plots of the different fertilizer applications, combinations, and rates, and using only the last-named value.

Under "Discussion of Results," references are made to residual effects of the fertilizers used. A residual effect of fertilizer may be
explained as an effect that is noticed in the succeeding crops in addition to the effect noted during the season in which it was applied. This statement must not be understood to mean that no benefit was derived from the fertilizer the season it was applied. The residual effects noted were in stubble cane on the plots to which fertilizer had been applied to the plant cane the preceding year. A residual effect of fertilizer may also be caused by an improvement in the condition of the soil as a result of the addition of organic matter or lime.

To be able to follow the discussion of the data and to understand the interpretations, it is necessary to refer constantly to the tables under consideration.

(See Tables 1, 2, and 3 inserted in back cover.)

DISCUSSION OF RESULTS

Mississippi Alluvium, First-Bottom Soils

PLANT CANE

A study of the data in Table 1 shows that the use of cyanamid on plant cane may or may not be profitable, according to the condition of the soil to which the cyanamid is applied.

Applied on the Mississippi Alluvium, First-Bottom Soils, at the rate of 100 pounds per acre, cyanamid does not produce profitable increases on soils where the fertility has been maintained year after year by rotation, cultivation, and the incorporation of organic matter. This was found to be true even where the legume crop preceding the plant-cane crop was pulled for hay.

The use of fertilizer on plant cane was found to be profitable where soils had been run down by continuous cropping and by neglecting to turn under organic matter, or by being allowed to grow in weeds for many years. This is true whether legumes were turned under ahead of the plant cane or were pulled for hay.

For example, the test at Dugas and LeBlanc was made on a highly-built-up soil, the fertility having been maintained by good farming practices, while the test at Alma Plantation was on soil of the same type which had been idle and growing weeds for a number of years. When the latter was rented from the owners and brought back into cultivation by Alma Plantation, corn and soybeans were planted, and the soybeans turned under preceding the planting of the cane.

The following fall when the cane crops were harvested, it was apparent that when it was very profitable to fertilize the one at Alma Plantation with cyanamid and superphosphate, or with ammonium phosphate 11-48-0, the other at Dugas and LeBlanc showed losses in every case except where 100 pounds of cyanamid alone was used, in which case the increase was slight.

No response to phosphoric acid was obtained on the fertile soil, while very profitable responses were noted on the neglected soil. Evidently the available phosphoric acid was high where organic matter
was allowed to decompose within the soil and low where the organic matter (wild growth) had decomposed on the surface. Samples of soil from the check plots of these two locations were analyzed for available phosphoric acid the following spring. The fertile soil contained 168 pounds of available \( P_2O_5 \) per acre. The other contained only 59 pounds per acre.

The time-of-application tests on plant cane were all conducted on the Mississippi Alluvium, First-Bottom Soils. Cyanamid applied in the fall before planting was somewhat more profitable than when applied in the spring. From the standpoint of tonnage produced, however, spring applications seem to show a slightly larger increase.

**FIRST-YEAR STUBBLE**

To study the supplemental use of phosphoric acid, applications were made to some plots every year and to others in the plant-cane year and not on the stubble. In the case of ammonium phosphate 11-48-0, a single application of 200 pounds per acre supplied the same amount of phosphoric acid in one year as was ordinarily applied by the annual use, for three years, of 200 pounds of superphosphate.

The test at the E. G. Robichaux Company on the Mississippi Alluvium, First-Bottom Soils showed increased yields from plots where cyanamid and superphosphate were applied in the plant-cane year as compared to plots that received no fertilizer. Both plots received 200 pounds of cyanamid on the first stubble, but the previous treatment of plant cane in one series of plots seemed to show a residual effect of the fertilizer applied. The increased value of the cane produced amounted to $3.34 (See Table 2).

At Raceland, where one crop of soybeans was turned under ahead of the cane, the residual effect of the fertilizer amounted to considerably more than at the E. G. Robichaux Company where two crops of soybeans were turned under. The difference in this case amounted to $13.96.

The test at the Estate of H. C. Minor on black land, where one crop of beans was turned under, showed no beneficial residual effects; in fact, a detrimental effect was indicated. This soil was in poor condition.

At J. W. Supple's, where alternate rows of legumes were turned under, there was no appreciable residual value from an application of 100 pounds of cyanamid on plant cane.

However, the first-year stubble at Alma Plantation was considerably better where cyanamid and superphosphate were applied to plant cane. The increased profit, which may have been, in part, a residual effect, was $30.87 on the plots that received the two fertilizers the preceding year.

Again, in the case of the test at Dugas and LeBlanc, where large crops of legumes had been turned under periodically, an advantage was shown as a result of maintenance of the soil in a high state of
fertility. Very profitable yields were obtained from all plots, but no residual effect was noted on first-year stubble where fertilizer was applied on the plant cane.

When the plots that received cyamid and superphosphate on the plant cane and first-year stubble are compared with those that received cyamid and superphosphate on the plant cane, but with cyamid alone on the first-year stubble, the extra application of superphosphate usually produced a detrimental effect which showed itself in decreased profits per acre. The successive applications of phosphoric acid no doubt caused an excess of P<sub>2</sub>O<sub>5</sub> in the soil, from which no benefit was secured. In two instances, however, increased profits were obtained where the extra phosphoric acid was applied. The average obtained from the five tests involved (J. W. Supple's not included) showed a loss of $6.68 per acre.

Comparisons between the plots that received ammonium phosphate 11-48-0 on the plant cane and plots that received cyamid indicate that there was, in the majority of cases, a greater residual effect from ammonium phosphate than from cyamid alone. The application on the first-year stubble, in both cases, was 300 pounds of cyamid per acre. But where previously the cane had received ammonium phosphate, the profits seemed to be slightly greater than where nitrogen was applied alone. In one case, at the Estate of H. C. Minor, cyamid produced the greater residual effect.

The average increase of the five tests was $1.31 per acre where ammonium phosphate was applied instead of cyamid. In this case, the residual effect may have been due to the phosphoric acid supplied in the 200 pounds of ammonium phosphate 11-48-0 (96 pounds P<sub>2</sub>O<sub>5</sub>) applied to the plant cane.

In comparing two series of phosphated plots, in one of which the nitrogen application was divided while the other received all of its nitrogen on the first-year stubble, the greatest benefits were derived from the plots which received the cyamid in one application, and that on the stubble. (Table 2).

Plots receiving 100 pounds of cyamid plus 200 pounds of superphosphate on the plant cane, and 200 pounds of both materials on the first-year stubble, produced less profit than plots which received the total cyamid application of 300 pounds per acre on the stubble. The average difference in the profit obtained was $7.09 per acre. On the average, an increased profit of $5.91 per acre was obtained by using 300 pounds of cyamid per acre instead of 200 pounds.

A series of tests was conducted on first-year stubble cane on the First-Bottom Soils in the Mississippi River and Bayou Lafourche region, where in every case soybeans were turned under ahead of the plant cane. It was noted that where there was no previous commercial-fertilizer treatment to the plant cane, the greatest profit was secured from 200 pounds of cyamid. Superphosphate at the rate of 200 pounds per acre, used in addition to the cyamid, produced a
somewhat smaller profit than that secured with the use of 200 pounds of cyanamid alone. The average tonnage produced per acre from the four tests was slightly in excess where both cyanamid and superphosphate were used than where cyanamid alone was used, but the per cent sucrose in the juices was lower, and lower profits were obtained. An application of 300 pounds of cyanamid per acre did not increase the profit over the 200-pound application in the one instance where it was used; in fact, the profit was $11.28 more per acre where 200 pounds were used.

Two tests to study the best time at which cyanamid should be applied for optimum results were conducted on the Mississippi River Soils at Kahns and Plaquemine. Knowing the necessity for moisture in the soil to bring about the necessary changes in cyanamid, precipitation records were secured. In every case, the soil was moist when the fertilizer was applied, and the decomposition of cyanamid was started immediately. There was no period in which the cyanamid remained inactive in the soil in either place. However, at Plaquemine the precipitations were more numerous and heavier during the months when the fertilizer was applied than at Kahns. While 18.50 inches of rain fell at Plaquemine during March, April, May, and June; Kahns received only 11.77 inches. The dates at which the fertilizer was applied were, in each case, about one month apart. The stand of cane at Kahns was better than at Plaquemine.

The results of these two tests indicated that 200 pounds of cyanamid, applied either early, around April 18, or late, produced a good profit, and that the most profitable time to apply the fertilizer is at the normal time of application, around April 18. The early application seemed to be slightly more profitable on the average than was the late, notwithstanding the fact that more tons per acre were produced on the plots which received the late application.

SECOND-YEAR STUBBLE

The 1932 second-year-stubble tests shown in Table 3 were fertilized according to the standard outline. All three tests that were carried on through three years were located on the Mississippi Aluvium, First-Bottom Soils. The plant cane and both stubble crops received fertilizer as indicated in the outline. In every case, legumes were turned under prior to the plant-cane crop.

At the E. G. Robichaux Company, those plots that received cyanamid and superphosphate on the plant cane, cyanamid on first-year stubble, and cyanamid again on the second-year stubble, produced more profit as second-year stubble than did those plots that received the same fertilizer on the stubble crops but no fertilizer on the plant cane. This additional profit or residual effect may be attributed to the effect of fertilizing the plant cane with cyanamid and superphosphate.

A comparison of the plots that received cyanamid and superphosphate all three years with plots that received cyanamid and
superphosphate on the plant cane but cyanamid alone on both stubble crops, indicated that the continuous application of phosphoric acid is not profitable. Where the crop received superphosphate only on plant cane, the cane produced was slightly more profitable than where superphosphate was applied every year. Where cyanamid and superphosphate were applied every year for three years, the production of cane was more profitable than where no phosphoric acid was applied at any time. No depressing effects from an excess of phosphoric acid were evident.

All plots which received 300 pounds of cyanamid on the second-year stubble produced cane of greater value per acre than did the 200- and 400-pound applications.

On the second-year stubble, an application of 300 pounds of cyanamid, supplemented with superphosphate, was slightly more profitable than cyanamid used alone. Both series of plots received the same amounts of phosphoric acid. In one case, ammonium phosphate was supplied in a single application, on the plant cane; while in the other case the phosphoric acid was applied in divided applications every year during the three years.

Cyanamid at the rate of 400 pounds per acre produced the highest acre yield, but this added tonnage was at a sacrifice of the per cent sugar in the cane. The value of the cane produced did not equal that obtained from the plots that received 200 pounds per acre (exclusive of the plots that were check plots as plant cane).

No residual effect from fertilizing plant cane was shown in the second-year-stubble test with Godchaux Sugars Inc., at Raceland. The plots which received cyanamid and superphosphate on the plant cane and cyanamid alone on both stubbles produced less valuable returns than the plots which received only cyanamid on the stubbles but no fertilizer on the plant cane. The plots which received cyanamid and superphosphate every year of the three did not produce as valuable second-year stubble as where the stubble crops received cyanamid alone but where no fertilizer was applied to plant cane.

The use of phosphoric acid only one year of the three seems to be sufficient. Where this was done, the value of the cane produced was more than it was where superphosphate was applied each year. There was no residual effect from the nitrogen supplied by ammonium phosphate at Raceland. In a comparison of two series of plots which received the same amounts of cyanamid on the stubble crops, but one of which had received ammonium phosphate on the plant cane while the other had received the same amount of phosphoric acid in three yearly applications of superphosphate, the latter plots produced slightly more profit per acre.

The plots which received 400 pounds of cyanamid on the second-year-stubble crop produced less profit than those that received 300 pounds per acre. The tonnage per acre was increased to a small
extent, but the per cent sucrose in the cane was decreased by the heavier nitrogen application.

The conditions under which the experiment on the Estate of H. C. Minor was conducted were not conducive to the optimum results from fertilizer. The drainage was poor on this black land, and the soil was in a very poor condition. The highest returns were secured from the plots that received cyanamid and superphosphate each year, including the plant cane. The cyanamid was applied to these plots at a rate of 200 pounds per acre on the stubble crops and 100 pounds on the plant cane. The rate of application of superphosphate (200 pounds per acre) was the same each of the three years.

In one of a series of first-year stubble tests on the same soil type where the plant cane was preceded by a crop of legumes turned under, the greatest increased profit was secured from 250 pounds of cyanamid applied to second-year stubble following the unfertilized plot of first-year stubble. A slightly smaller increase in profit was obtained by the use of 300 pounds of cyanamid at this test (Raceland).

Applications of superphosphate with 250 pounds of cyanamid, where the previous treatment was 200 pounds of cyanamid plus 200 pounds of superphosphate, produced more profit than an application of 250 pounds of cyanamid where the previous treatment was an application of 200 pounds of cyanamid. However, the production on both plots was less than where 250 pounds of cyanamid were applied following an unfertilized plot.

In a test with the South Coast Company, the use of superphosphate with cyanamid on the two stubble crops produced more profit than cyanamid used alone both years. The rate of applying cyanamid to these two series of plots was the same, and therefore comparable. When the rate of cyanamid was increased to 300 pounds per acre, the returns were less than where 250 pounds were applied alone or where 250 pounds were applied with superphosphate.

The test on the Estate of H. L. Laws showed the greatest profit from 250 pounds of cyanamid applied to cane that had received no fertilizer the previous year. The use of the supplemental superphosphate with 250 pounds of cyanamid showed a small increased profit over the unfertilized plot, but the increase was considerably less than where cyanamid was applied alone at the same rate. The higher application of 300 pounds of cyanamid per acre produced less profit than did 250 pounds. The extra nitrogen did not seem to be utilized economically by the cane during 1930, the year of these tests.

Two tests, conducted at Glenwood Sugars and the South Coast Company, were slightly different from the tests mentioned above, in that no unfertilized check plots were retained. The most profitable application of cyanamid in one case, that of Glenwood Sugars, appeared to be 300 pounds per acre. The increased yield was about three tons per acre over the plots which received 250 pounds of
cyanamid. Both series of plots to which 250 pounds of cyanamid alone were applied, produced a more valuable return than the series that received the phosphoric acid in addition to the cyanamid. The phosphoric acid seemed to produce a depressing effect on the yield of sugar per ton without producing a measurable effect on the tonnage per acre.

The test with the South Coast Company at Houma showed somewhat different results. An application of 250 pounds of cyanamid where 200 pounds were previously applied to first-year stubble seemed to be the most profitable rate to apply to second-year stubble instead of the 300-pound application, as at Glenwood Sugars. The plots that were check plots as first-year stubble did not produce as profitable yields as did those that received 200 pounds of cyanamid, when 250 pounds of cyanamid were applied on the second-year stubble. There seemed to be a residual effect in this case from the fertilizers applied to the first-year stubble. Supplementing cyanamid with phosphoric acid during both stubble years did not seem to give any increase over the plots where cyanamid alone was applied only to the second-year stubble.

**Coastal Prairie Sedimentary Soils**

**PLANT CANE**

In one plant-cane test on the Coastal Prairie Sedimentary Soils, where a legume crop had been turned under previous to the plant cane, there were indications that the soil was deficient in both nitrogen and phosphoric acid. Cyanamid used alone was very profitable, but cyanamid supplemented with superphosphate was even more profitable. Ammonium phosphate 11-48-0 showed more profit than did cyanamid alone, but less than cyanamid plus superphosphate. The use of superphosphate alone, although it depressed the tonnage per acre, seemed to produce cane with a higher per cent sucrose, resulting in a profit. However, this profit was considerably less than where nitrogen was applied with superphosphate.

**FIRST-YEAR STUBBLE**

One test on Coastal Prairie Sedimentary Soils which produced a distinct profit from the fertilization of the plant cane even after a crop of soybeans turned under, showed no residual effect of cyanamid, superphosphate, or ammonium phosphate 11-48-0, as all plots which received fertilizers the preceding year produced cane less valuable than the plots which had received no fertilizer.

Plots which received cyanamid and superphosphate on the plant cane and again cyanamid and superphosphate on first-year stubble showed a distinct profit over another series of plots that had received the same treatment on plant cane but received only 200 pounds of cyanamid on the stubble. This residual effect was not evident in the Mississippi Alluvium, First-Bottom Soils, as the additional application of phosphoric acid produced no profit.
An application of 300 pounds of cyanamid seemed to produce more profit where the preceding application was cyanamid rather than ammonium phosphate. The residual effect secured was from cyanamid on this soil type in contrast to a residual effect from ammonium phosphate on the Mississippi Alluvium, First-Bottom Soils.

The Coastal Prairie Sedimentary Soils act similarly to the Mississippi Alluvium in that more profit was secured from plots that received 300 pounds of cyanamid on the stubble rather than 100 pounds on the plant cane and 200 pounds on the stubble. The average profit produced by the use of 300 pounds of cyanamid per acre was slightly less than that produced where 200 pounds were used.

The use of phosphoric acid was again profitable on the Coastal Prairie Sedimentary Soils, in the test located with M. A. Patout, in which the most profitable application of fertilizer was cyanamid plus superphosphate. A small profit was obtained from the use of 200 pounds of cyanamid alone, but an increased profit was shown when 200 pounds of superphosphate were used with the cyanamid. Where 300 pounds of cyanamid were applied, a loss of $2.84 was sustained.

Mississippi-Red River Sedimentary Soils

PLANT CANE

Tests on the Mississippi-Red River Sedimentary Soils found along Bayou Teche, where the legume crop was pulled for hay, showed that profitable returns were secured from all fertilizer application, with cyanamid used alone producing the highest returns. Supplemental use of superphosphate with cyanamid did not increase the returns, nor did phosphoric acid in combination with nitrogen applied in ammonium phosphate 11-48-0 show any increase over nitrogen alone. Phosphate had no measurable effect on the per cent sucrose in the juice.

FIRST-YEAR STUBBLE

On Mississippi-Red River Sedimentary Soils, one test of first-year stubble, which was a continuation of the plant-cane test discussed above, indicated that 200 pounds of cyanamid was more profitable where it was preceded by cyanamid and superphosphate than where no fertilizer was previously applied.

The application of additional phosphoric acid on stubble cane seemed to produce additional profit at this location. Where cyanamid and superphosphate were applied to cane during the plant-cane and stubble years, a greater profit was indicated than where the plant cane received both cyanamid and superphosphate but only cyanamid was applied to the stubble. Where ammonium phosphate 11-48-0 was previously applied to plant cane, 300 pounds of cyanamid to stubble cane produced a slightly increased profit over the plots where cyanamid was applied to both plant and stubble. Two hundred pounds of cyanamid was a more economical rate than was 300 pounds.
A test of stubble cane on the Mississippi-Red River Sedimentary Soils, at Levert-St. John, where legumes were turned under preceding plant cane, showed a profitable increase from an application of 100 pounds of cyanamid per acre. On the plots that received 200 pounds, the profit was almost double that obtained from the 100-pound application. However, 300 pounds per acre produced the largest increase in tonnage but with a decrease in the percentage of sucrose, and showed a smaller profit than did 200 pounds of cyanamid, but more than the 100-pound application.

The other test on this type of soil, where half of the legume crop was turned under, was conducted with the J. M. Burguieres Company. Cyanamid at the rate of 200 pounds per acre gave a very profitable increase, but the increase was considerably less than from the 300-pound application. In this case it was evident that the additional nitrogen supplied was profitably utilized. Superphosphate, applied with 200 pounds of cyanamid, produced less profit than where the cyanamid was applied alone.

SECOND-YEAR STUBBLE

In a test of second-year stubble on Mississippi-Red River Sedimentary Soils that had previous fertilizer treatment and a half crop of legumes turned under, it was indicated that 300 pounds was the most economical rate of cyanamid to apply. Cyanamid at the rate of 250 pounds per acre, applied to plots that were check plots the first year, produced a slightly increased profit over the plots that had previously received 200 pounds of cyanamid. No residual effect on the second-year stubble was evident from the use of fertilizer on the first-year stubble crop. The lowest returns were secured where supplemental superphosphate was used. (See Table 3).

REVIEW OF LITERATURE

DECOMPOSITION AND TRANSFORMATION OF CYANAMID IN THE SOIL

When cyanamid is applied to the soil, it must undergo decomposition before the nitrogen can be assimilated by plants. The course of this decomposition, however, has long been in dispute. Much has been written on this subject. Only the most consistent reports are reviewed here.

The chemical changes which cyanamid undergoes in the soil are rather complex. The consensus of opinion of many investigators is that there is no direct bacterial action on cyanamid. Rather, it is thought that the bacteria act on the transformation products of this fertilizer material (1).

Under suitable conditions as to temperature and moisture, soils containing clay and organic matter cause a rapid conversion of

* This and subsequent numbers in parenthesis refer to the bibliography.
cyanamid to urea and hydrated lime. Urea, in turn, is broken down to ammonium carbonate and then to nitrate by biological action. Small amounts of other compounds may be formed at the same time.

Micro-organisms play no part in the first stage. The transformation proceeds with maximum intensity during the first moment of contact with the soil and then continually becomes slower. It proceeds in the same manner when used in larger acre applications, the quantity of urea produced at the end of a given time being dependent upon the amount of cyanamid applied. The phenomenon takes place equally well in the presence of antiseptics and with sterilized soil.

The transformation into urea is effected by the colloidal substances of the soil. If the colloids are destroyed by calcination or by treatment with acids or alkalies, the soil loses the power of effecting the transformation into urea, but again acquires it when treated with a colloidal material. The colloids act as catalysts through the enormous specific surfaces which they afford.

The ammonia liberated by the action of bacteria on ammonium carbonate is readily absorbed by the soil, this causing an acceleration by removing one of the products of decomposition. The ammonia is then acted upon by the nitrifying bacteria, gradually being converted into nitrate of lime.

**NITRIFICATION OF CYANAMID**

In a series of experiments covering periods of 35 to 162 days (6), in which analyses were made for nitrate and ammonia, cyanamid when used alone changed quantitatively to nitrate in about 80 days. Although at first slightly slower, due to the fact that the cyanamid had to undergo other changes before it was converted into ammonia, the nitrification of cyanamid was almost parallel with that of sulphate of ammonia.

Nitrification of cyanamid occurs at a higher rate in loam and clay soils than in sandy soils (7). Sandy soils have a low moisture-holding capacity, and do not have a high degree of bacterial activity, because bacteria must have moisture and organic matter for their best development. Sandy soils are quite often deficient in organic matter, and in dry weather they are deficient in moisture. The texture of loam and clay soils allows them to maintain a higher moisture and organic matter content than do the lighter soils. Cyanamid is nitrified at a higher rate where the bacterial numbers are large than where they are limited.

When cyanamid is applied in soils that are deficient in nitrifying bacteria, ammonia may be lost into the air if it is not utilized and converted into nitrate as fast as it is formed. Losing ammonia into the air under these conditions will produce a low nitrogen-recovery rate from the use of cyanamid. This is true of all fertilizer materials which decompose in the soil with the liberation of ammonia, such as ammonium sulphate and cottonseed meal (20).
CYANAMID AND THE MICRO-ORGANISMS OF THE SOIL

Cyanamid produces unusually large increases in the number of organisms in the soil (2), the maximum increase ordinarily occurring within two weeks after application. The rate of increase in numbers depends upon the quantity of cyanamid applied and the temperature of the soil. Both the lime and calcium cyanamide content of cyanamid are very important in promoting increased bacterial activity. Under favorable conditions in the soil, the cyanamid nitrogen is almost completely transformed by bacteria (12).

Usually, in conducting experiments to determine the effect of cyanamid on the soil organisms, the quantities used are far in excess of field practice. However, when cyanamid is added to the soil in the amounts per acre usually employed as a fertilizer, the number of bacteria present in the soil is first decreased, as a result of the liberation of hydrated lime and free cyanamid, and then markedly increased, after the caustic effects disappear (26).

EFFECT OF CYANAMID ON SOIL REACTION

Long-continued studies have shown that when a compound of ammonia (or urea) is decomposed in the soil, an acid condition is produced (23). If the soil is not well buffered the acid condition brought about by such materials as sulphate of ammonia, for instance, may assume such proportions as seriously to lower the productivity of the soil. The use of such fertilizing materials, therefore, will sooner or later develop the necessity of applying lime to correct the acidity of the soil.

Lime can be applied separately to counteract the acid-forming tendency of such a fertilizer material. However, some investigators believe that the most feasible way of adding lime is in the synthetic fertilizer itself. This calls for the production of a nitrogen material which contains lime, or some other product that is physiologically basic.

Cyanamid is such a product. It causes a progressive increase in alkalinity during the first five to ten days after its application (22). Later this alkalinity decreases somewhat. The final result, however, is a distinct change in the pH toward alkalinity.

Cyanamid gives satisfactory results on very acid soils. When used in conjunction with superphosphate and kainit on unlimed soils, higher crop yields are often obtained than with ammonium sulphate. The favorable effects of cyanamid are attributed to its ability to reduce the acidity of acid soils. In this respect it is superior to sodium nitrate or basic slag (25).
INFLUENCE OF SOIL FERTILITY ON FERTILIZING ACTION
OF CYANAMID

Cyanamid is not adapted for use on acid-humus soils, nor to light sandy soils containing very little clay or organic matter (3). On such soils the results are improved by the use of manure which supplies the necessary micro-organisms for transforming the urea to nitrate.

Cyanamid should be applied to or cultivated into moist soil. If well worked into the soil the rate of change from cyanamid to urea is increased (8). Nitrification begins and is completed much more rapidly in soils rich in organic material and in clayey soils than in very sandy soils.

In soils that have a low moisture-holding capacity, in highly acid or very alkaline soils, or in those containing little or no organic matter, cyanamid does not produce optimum results because these conditions do not foster the best growth and development of the bacteria that serve to transform it into ammonia and nitrate. The conditions which are most favorable to ammonification, nitrification, and like bacterial processes in the soil are also most favorable to the most efficient action of cyanamid.

CYANAMID IN MIXED FERTILIZERS

When cyanamid was first introduced, it was frequently stated that it could not be mixed with superphosphate, since it caused "reversion" of phosphate and loss of nitrogen (4). The quantity of nitrogen lost from such mixtures is normally of little consequence. However, there may be a reduction in the availability of the phosphoric acid of the superphosphate.

A mixture of one part of cyanamid with ten parts of superphosphate may result in the conversion of all "water-soluble" phosphoric acid into "citrate soluble"; and one part with five parts of superphosphate leads to a change of the whole of the phosphoric acid into di-calcium phosphate. The citrate-soluble and the di-calcium phosphate both are quite available to plants.

Cyanamid is an excellent conditioner for use in the formulation of mixed fertilizers, producing a mixture which is easily drilled and not liable to cake (1). The lime neutralizes any free acids in the mixture, thereby preventing bag-rotting. It improves the mechanical condition by its drying action.

Commercial fertilizer mixtures in which cyanamid has been used at a rate of not to exceed 60 pounds per ton usually contain little or no calcium cyanamide in a few hours after they are mixed. Urea is the chief of the nitrogenous-transformation products, but small amounts of other compounds are also formed. Dicyanodiamid does not form in quantities except where the cyanamid is mixed with superphosphate in proportions much higher than those commonly used.
Where large amounts of cyanamid are used in the preparation of cyanamid-superphosphate mixtures on the farm, the phosphate should be as dry as possible, and the temperature kept from rising appreciably by mixing in small lots or thin layers.

EFFECT OF STORAGE ON CYANAMID

Under dry storage conditions, the loss of nitrogen in the storage of cyanamid is practically negligible (27). The loss of nitrogen suffered by cyanamid has been ascertained by determining the actual ammonia evolved (11). Under the most severe conditions, that is, exposure for 50 days in a constantly-changing atmosphere saturated with water vapor, the loss of nitrogen amounted to only 2.05 per cent of the total nitrogen originally present.

Storage of cyanamid for six to ten months does not generally reduce its effectiveness as long as it is well protected from dampness (19). The determination of dicyanodiamid is considered to be a safe basis of evaluating the value of stored cyanamid. If the content of dicyanodiamid nitrogen is greater than 10 per cent of the total nitrogen, the effectiveness is reduced.

When cyanamid, stored for seven or eight years and containing 9.11 per cent dicyanodiamid, was compared with fresh cyanamid, the latter was twice as effective as the old material (24).

It is advisable to use fresh cyanamid for experimental purposes. The nitrogen of any dicyanodiamide formed from long storage in open bins becomes available only very slowly in the soil.

CYANAMID AS A FERTILIZER FOR SUGAR CANE

Experiments with cyanamid have been conducted on the fertilization of sugar cane by the Louisiana Sugar Experiment Station, Puerto Rico Experiment Station, Queensland (Australia) Experiment Station, and the Java Experiment Station.

Louisiana—In tests conducted at the Louisiana Agricultural Experiment Station (13), cane fertilized with cyanamid gave a yield of 18.52 tons in comparison with 18.62 for nitrate of soda, 17.63 for sulphate of ammonia, 19.32 for tankage, 17.19 for cottonseed meal, and 17.18 for ammonium nitrate.

The increased yields due to a standard application of 36 pounds of nitrogen varied from 49.6 to 91.7 per cent when first-year stubble was under consideration, and from 21.1 to 48.5 per cent for plant cane (14) (15). Ammonium nitrate gave the greatest increase in tonnage, followed by cyanamid, sulphate of ammonia and nitrate of soda. Of the organic nitrogenous fertilizers, cottonseed meal gave better results than did tankage.

In the source-of-nitrogen tests in 1928 and 1929, six different materials were used; nitrate of soda, sulphate of ammonia, cyanamid, urea, calcium nitrate, and leunasalpeter. The increases were profit-
able in all cases. Nitrate of soda gave the highest returns, with leunasalpeter, sulphate of ammonia, calcium nitrate, cyanamid, and urea grouped closely together in the order named, showing an average increase of about 10 tons of cane from an application of 36 pounds of nitrogen per acre (16).

Four rates, 20, 40, 60, and 80 pounds of nitrogen per acre, of the more common carriers, sulphate of ammonia, cyanamid, calcium nitrate, calurea, and nitrate of soda were replicated twice on a very uniform body of Yazoo very fine sandy loam, where the stand of cane was extremely even (21). The yield in tons of sugar cane per acre showed, in nearly every case, a steady increase up to applications of 80 pounds of nitrogen per acre, whereas the pounds of sugar per acre indicated no economic return beyond the 40 pound rate. There was little difference in the action of the several carriers of nitrogen.

Four years' experiments with different sources of nitrogen on plant cane and three years' results on stubble cane, conducted on Mississippi Alluvium, First-Bottom Soils, have been reported (17). In addition to 36 pounds of nitrogen per acre, each plot received the full ration of phosphoric acid and potash (36 pounds of P₂O₅ and 35 pounds of K₂O per acre) except the check plots, which did not receive any fertilizer. The sources of nitrogen were: sodium nitrate, ammonium sulphate, urea, cyanamid, and calcium nitrate.

There did not seem to be any material difference in the tonnages produced by the different sources of nitrogen, although urea did not produce quite as much as did the other sources.

The increases due to the nitrogen fertilizer used on plant cane were not profitable. The cost of the fertilizer and the cost of application very nearly equaled the value of the additional cane produced.

Nitrogen produced greater increases in stubble than in plant cane. Phosphoric acid and potash used alone were not profitable, but all the increases from the use of nitrogen were very profitable. The different sources of nitrogen produced about the same increases, except that the increase from calcium nitrate was slightly higher than any of the others.

**Puerto Rico**—In experiments conducted in Puerto Rico, the several nitrogen materials were applied at the rate of 144 pounds of nitrogen per acre in two applications at an interval of two months (5). Cyanamid produced nine to thirteen tons per acre more cane, and one and one-half to two and one-half more 96° sugar per acre, than did any of the other nitrogen materials.

Five experiments conducted at Guanica Centrale in Puerto Rico indicated that tankage is a more effective source of nitrogen than ammonium sulphate or sodium nitrate (18). The two experiments in which cyanamid was used indicated that this fertilizer was more effective than any of the others.
Australia—The Australian experiments were with different forms of nitrogen applied to sugar cane (plant crop) at the rate of 100 pounds of nitrogen per acre (9). The yields, in tons of sugar per acre, were as follows: dried blood 8.5; ammonium sulphate 7.8; nitrolime (cyanamid) 7.8; nitrate of ammonia 7.4; and nitrate of soda 7.3.

Java—In Java, out of 59 tests, the yield of cane produced by using cyanamid was equal to that produced by ammonium sulphate in 29 cases, less in 25, and more in five (10). On the basis of sugar per acre the yield from cyanamid was equal to the yield from ammonium sulphate in 22 cases, less in 27, and more in nine. The average in favor of the ammonium sulphate was 2.5 per cent on cane per acre and 2.0 per cent on sugar.

BIBLIOGRAPHY

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15. — Thirty third annual report 1921 p. 5. Sugar cane investigations.


17. — Average of several years results. Sugar cane investigations. 1928-31.


### Table 1: Plant Cane

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<th>Year</th>
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<th>Crisp Preceding</th>
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#### Table 2: First-Year Stubble

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#### Table 3: Second-Year Stubble

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## PLANT CANE

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**Note:** Further fertilizer treatment is recommended. Hot in average. Check stubble, unless otherwise indicated. Not for several years. Work only with water and company.

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## SECOND-YEAR STUBBLE

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