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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 398 JUNE, 1929

DIVISION OF AGRONOMY

FERTILIZERS FOR RICE IN TEXAS

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**In cooperation with U. S. Department of Agriculture.
***In cooperation with the School of Agriculture.

Experiments with fertilizers on rice at Substation No. 4, Texas Agricultural Experiment Station, Beaumont, Texas, show that the soils responded to nitrogen and phosphoric acid, but nitrogen was needed more than phosphoric acid. During the thirteen years of the experiment, the application of 100 pounds of sulphate of ammonia per acre made the largest average yield of rice, 2,353 pounds per acre, or 553 pounds per acre more than the yield of rice on unfertilized soil. This was the most profitable treatment, making an average profit of $9.65 per acre for the thirteen years of the experiment and $4.55 per acre a year during the last five years. Cottonseed meal and manure were not as good sources of nitrogen as sulphate of ammonia.

The use of 150 pounds of 16 per cent superphosphate per acre increased the yield of rice 239 pounds per acre a year during the thirteen years of the experiment. The treatment of 150 pounds of superphosphate and 75 pounds of sulphate of ammonia made an average yield of 2,208 pounds of rice per acre, or 408 pounds more than the yield of rice on unfertilized soil. Both of these treatments made an average profit of approximately $4.00 per acre during the period.

Applications of fertilizers made after the rice was planted produced larger yields than applications made at planting time. The largest yield resulted from fertilizers applied six weeks after the rice was planted. The application of 100 pounds of sulphate of ammonia, six weeks after planting, however, made an average increase of only 98 pounds of rice per acre more than the application at planting time. This increase is not enough to justify the trouble and expense involved in applying the fertilizer at a separate operation. On the other hand, the application of 150 pounds of superphosphate alone and with 100 pounds of sulphate of ammonia per acre six weeks after planting made average yields of 254 and 374 pounds per acre, respectively, more than the yield resulting from the same treatments applied at planting time. These are significant and profitable increases and indicate that superphosphate, whether used alone or with sulphate of ammonia, should be applied about six weeks after planting.

When yields and profits resulting from the use of fertilizers and the convenience of applying fertilizers are considered, the results reported in this Bulletin show that 100 pounds of sulphate of ammonia per acre applied at planting time is perhaps the best fertilizer practice for rice in Texas, especially in the Beaumont district. The use of (a) 50 pounds of sulphate of ammonia per acre, (b) 150 pounds of superphosphate, and (c) 300 pounds of superphosphate and 100 pounds of sulphate of potash per acre, however, made substantial profits. These results are probably applicable to similar soils in other parts of the rice-belt of Texas.

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FERTILIZERS FOR RICE IN TEXAS

E. B. REYNOLDS AND R. H. WYCHE

Rice was grown to a small extent without irrigation in Texas perhaps as early as 1863, but the crop did not become of commercial importance until more than thirty years later. There were 335 acres of rice in Texas in 1879 and 178 acres in 1889, according to the United States Census. The growing of rice on a commercial scale in Texas really began in 1897 with the advent of irrigation, and the industry received a great impetus from the success of the rice growers in southwestern Louisiana. By 1899, the acreage devoted to rice in Texas had increased to 8,711 acres, all of which was in the Beaumont district, except 200 acres in Colorado County. The industry developed rapidly during the next decade. Texas grew 237,568 acres of rice in 1909; 164,481 acres in 1919; and 145,926 acres in 1924, according to the United States Census. The largest acreage of rice in Texas in any year was 303,000 acres, which occurred in 1913. Since then the acreage has gradually declined until in 1928 there were only 160,000 acres.

In 1879, Texas had 0.2 per cent of the rice acreage in the United States; 0.1 per cent in 1889; 2.5 per cent in 1899; 38.9 per cent in 1909; 18 per cent in 1919; and about 16 per cent in 1927.

The rice-growing industry in Texas first developed around Beaumont and was undoubtedly stimulated by the success of the rice growers in southwestern Louisiana. In 1899, there were 5,859 acres of rice in Jefferson County, which was 62 per cent of the rice acreage in Texas. There were 2,347 acres devoted to rice in Orange County in 1899. The industry gradually spread westward and southwestward. In 1919, Matagorda County grew 37,927 acres of rice, or only 5,000 acres less than Jefferson County, while in 1924 there were 61,599 acres of rice in Matagorda County as compared with 16,871 acres in Jefferson County. Wharton County ranked second in acreage in 1924 with 23,638 acres. In 1924, the center of rice production in Texas was in Matagorda, Jackson, and Wharton Counties, according to the United States Census.

While the rice-growing industry in Texas was established on a commercial scale in 1897, it was not until 1909 that experimental work was planned to study the problems involved in the production of rice in the State. In 1909, the Rice Experiment Station was established at Beaumont in Jefferson County. Since that time the experiment station has made studies on some of the main problems encountered in the growing of rice, such as the testing of varieties; selection and breeding; methods of production, including time, method, and rate of seeding; irrigation; rotations; and the use of fertilizers.

During the first few years of rice-growing in the State, little or no attention was given to the use of commercial fertilizers. It was the common practice for the farmers to grow rice on the same land year after year until the yields became unprofitable, and then they would move to new land. As the acreage of virgin, or sod, land suitable for rice decreased and the yield of rice on old land declined, many farmers began to use commercial fertilizers in an attempt to increase the yield of rice.

At the present time it is estimated by the American Rice Growers Cooperative Association* that approximately 60 per cent of the rice farmers in the Beaumont district use commercial fertilizers in some form. During the season 1925-1926, 762 tons of fertilizer were sold in Jefferson County, although the average yearly sales for the fifteen years, 1911 to 1926, were about 1,370 tons. It is not known, however, how much of this fertilizer was used on rice. Superphosphate (acid phosphate) seems to be the principal fertilizer used, although some sulphate of potash was sold. This fertilizer practice has developed without any experimental evidence and apparently is based entirely on the experience and opinion of farmers; but the opinion of farmers is not in general agreement as to the best fertilizer practice. It is estimated that one-third of those who use fertilizer on rice regard the practice as unprofitable, although the yield of rice is increased somewhat, while others are of the opinion that the practice is profitable. In the Beaumont district, the farmers who do not use fertilizer for rice are farming the heavier soils. While small amounts of fertilizers are sold in Colorado, Jackson, Matagorda, and Wharton Counties, which comprise the western part of the rice-growing area of Texas, apparently little fertilizer is used on rice in the area.

SOILS AND RAINFALL OF THE RICE-GROWING REGION OF TEXAS

Rice requires a rather high temperature and an adequate and dependable supply of water for irrigation during the growing season. Rice grows well on many kinds of soil but usually produces larger yields on the heavier types of soil, such as silt loams and clays, with almost impervious subsoils. Subsoils of this character are a distinct advantage because they prevent excessive percolation of water down through the soil and are therefore conducive to the most efficient use of irrigation water. The soils and climatic conditions of the humid part of the Gulf Coastal Plains of Texas are well adapted to the growing of rice. The humid part of these Plains, extending from the Sabine River on the east to the San Antonio River on the west, comprises the rice-growing region of Texas. The topography of the region is generally flat, the elevation increasing about one foot to the mile

*This information was furnished by Mr. A. H. Boyt, President, American Rice Growers Cooperative Association, Beaumont, Texas.

inland from the Gulf of Mexico. This gentle slope allows fairly adequate surface drainage and at the same time it is favorable to the holding of irrigation water on comparatively large areas of land by field levees. The region consists mostly of open prairies, except along the stream bottoms, which are usually heavily timbered. The following counties comprise the greater part of the rice-growing region of the State: Brazoria, Chambers, Colorado, Fort Bend, Galveston, Harris, Jackson, Jefferson, Liberty, Matagorda, Orange, Waller, Wharton, and Victoria.

Soils

The principal rice soils are the gray to brown or almost black soils underlain by heavy, almost impervious clay subsoils. These soils are classified into several different types. Lake Charles clay, which has a dark gray to black surface soil underlain by a gray almost impervious clay subsoil, is perhaps the most important rice soil of the region. Crowley clay has a brownish-gray to brown surface soil which is underlain by a bluish gray, sticky clay subsoil, mottled with yellow and brown. This is an important rice soil locally in the eastern part of the rice-growing area, but it is not nearly so extensive as the Lake Charles soils. While the Lake Charles soils are the more desirable soils for rice, the crop is grown to some extent on the gray soils of the Edna series.

Rainfall

The average yearly rainfall at several points in the rice-growing area of Texas is shown in Table 1. The data in the table were taken from the United States Weather Bureau, "Climatological Data: Texas Section," annual summary for 1927. In this table the stations are arranged in order from east to west; that is, the eastern-most station appears first in the table and the others follow as one proceeds westward. It will be observed that the yearly rainfall decreased gradually from east to west. For instance, the average yearly rainfall is 49.73 inches at Beaumont, in the eastern part of the area, and 36.87 inches and 35.66 inches at Edna and Victoria, respectively, in the western part of the area. This is a difference of about 14 inches in the rainfall at Beaumont and Victoria, which are approximately 200 miles apart.

Irrigation

The larger streams of the area, such as the Neches, Trinity, Brazos, and Colorado Rivers, are the main sources of water used for the irrigation of rice. Artesian water, however, is available in some sections. While there are large areas of soil suitable for the growing of rice, all of these areas are not accessible to the available sources of water.

The amount of water required for irrigating rice depends upon several factors: (1) The individual user of water, (2) the nature of the soil, and (3) the amount and distribution of rainfall. More water

is required in years of light rainfall than in years of heavy rainfall. In general, however, about 24 inches of water is used in an average season in the rice-growing region of Texas.

Table 1.—Average yearly rainfall in inches at different places in the rice-growing area of Texas.

Place	County	Rainfall, inches	Length of record, years
Orange	Orange	42.42	20
Beaumont	Jefferson	49.73	34
Liberty	Liberty	49.74	24
Houston	Harris	45.84	38
Rosenberg	Fort Bend	42.39	13
Brazoria	Brazoria	47.85	37
Matagorda	Matagorda	44.43	18
Danevang	Wharton	42.31	32
Edna	Jackson	36.87	19
Victoria	Victoria	35.66	33

REVIEW OF FERTILIZER WORK ON RICE IN THE UNITED STATES

Experiments with fertilizers on rice have been conducted at the Rice Experiment Station, Crowley, Louisiana, since 1910. These experiments have been conducted on Crowley silt loam, which is the typical rice soil of the rice-growing area in southwestern Louisiana. The results of the work published in the Twenty-eighth Annual Report of the Louisiana Agricultural Experiment Station (1915) stated that the use of 200 pounds of acid phosphate (superphosphate) per acre produced the most profitable rice crops five years in succession. Potash salts did not produce appreciable increases in yield. It was found also that readily available forms of nitrogen were better than organic forms of nitrogen for Honduras rice, but there was not much difference in the two forms of nitrogen for the late-maturing varieties.

The Twenty-ninth Annual Report of the Louisiana Agricultural Experiment Station (1916) stated: "It is believed that sufficient data have been gathered during the past seven years to warrant discontinuing experiments which involve the continuous use of commercial fertilizers in an attempt to force land to grow rice year after year without rest or crop rotation."

Later, it was reported in the Thirty-fifth Annual Report of the Louisiana Agricultural Experiment Station (1923) that the fertilizer experiments at Crowley had shown that no commercial fertilizer could be relied upon to sufficiently increase or maintain the yield of rice on land similar to the soil, the Crowley silt loam, on the Rice Experiment Station at Crowley.

The results of the fertilizer work at the Rice Experiment Station, Crowley, Louisiana, from 1919 to 1923, inclusive, were published in United States Department of Agriculture Bulletin 1356 (1925). Superphosphate (acid phosphate), sulphate of ammonia, nitrate of

soda, cottonseed meal, dried blood, sulphate of potash, manure, and lime were used. During the five years dried blood, manure, and sulphate of potash were the only fertilizer treatments that produced larger yields than unfertilized soil, but the yield of rice was not increased enough to pay the cost of the fertilizers. It was concluded from these results that commercial fertilizers were not profitable under the conditions at Crowley. The practice of growing soybeans and plowing under the soybean plants after harvesting the beans and planting rice on the land the following year gave an increase in yield of 915 pounds of rice per acre, or 63.6 per cent over the yield of rice on unfertilized land.

The United States Department of Agriculture has conducted experiments with fertilizers on rice at the Biggs Rice Field Station, Biggs, in the Sacramento Valley of California. The results of the work were published in Bulletin 1155 of the United States Department of Agriculture (1923). The work was done on Stockton clay adobe soil, which is reported as being representative of a large part of the rice-growing area of California. Applications of 350 pounds of superphosphate, 100 pounds of sulphate of ammonia, and 100 pounds of sulphate of potash per acre were applied alone and in all combinations. Nitrate of soda, cottonseed meal, dried blood, lime, and manure were also included in the experiment. During the three years 1914, 1915, and 1916, the application of one ton of manure per acre produced the largest average yield, 4,488 pounds per acre, or 879 pounds more than the yield of the untreated check plats. Sulphate of ammonia made the second highest yield, 4,260 pounds per acre, which was an increase of 651 pounds per acre over the yield of the check plats. Dried blood and cottonseed meal increased the yield 646 and 583 pounds per acre, respectively. The use of superphosphate and sulphate of ammonia together increased the yield 364 pounds per acre.

The California Agricultural Experiment Station in Bulletin 454 (1928) reports the results of experiments with sulphate of ammonia as a fertilizer for rice. In 1925 and 1926, the application of 100 pounds of sulphate of ammonia made an average increase of 645 pounds of rice per acre more than the untreated plats. In 1927, the application of 150 pounds of sulphate of ammonia per acre produced an increase of 1,198 pounds of rice per acre over the yield of the unfertilized plats.

OBJECT OF THE FERTILIZER EXPERIMENT

As mentioned in the introduction, experiments were begun to study the use of fertilizers on rice soon after the Rice Experiment Station was established. The main objects of these experiments were to determine (1) the best kind and amounts of fertilizer to use, and (2) the optimum time (stage of growth of rice) to apply fertilizers to rice. The purpose of this Bulletin is to report the results obtained in conducting these experiments from 1915 to 1928, inclusive.

METHOD OF CONDUCTING THE EXPERIMENT

The fertilizer work at Beaumont has been done on Crowley clay and Lake Charles clay soils. The Lake Charles clay is the most important soil for rice in Texas, while the Crowley soils, especially the Crowley silt loam, are the main rice soils in southwestern Louisiana. These soils are rather difficult to work, but if they are managed properly a good seed-bed can usually be obtained. The Lake Charles and Crowley soils are naturally productive and are well adapted to the growing of rice.

Size of Plats

The size of plats has varied somewhat during the course of the experiment. In the earlier years of the work the plats were one-tenth acre in size and usually the treatments were not replicated. Since 1921, the plats have been 1/33 to 1/22 acre in size and each fertilizer treatment has been replicated two or more times in the test each year. Each plat was surrounded by a levee. This served the purpose of watering each plat to the same depth and prevented the fertilizer treatment on a plat from influencing the yield on adjacent plats.

Plowing the Land

Usually the land in the fertilizer work was plowed in the late fall after the rice was harvested, but sometimes it was not possible to plow the land at that time on account of rainy weather. If the plowed land became foul with weeds, it was disked thoroughly to kill the weeds. A good seed-bed was prepared by disking and harrowing previous to planting the rice. While the preparation of the seed-bed was not uniform during the 13 years of the experiment, it was the same for all plats each year.

Rate of Seeding Rice

The rate of seeding the rice in the experiment has varied somewhat but in any year the rate of seeding was the same for all plats in the experiment. In most cases the rate of seeding has been 95 pounds per acre. Blue Rose, a late-maturing variety, was used in the fertilizer work in 1916, 1917, 1918, 1922, 1923, and 1927. Texas Fortuna, a medium late-maturing variety, was grown for six years. Early Prolific, an early variety, was used in the experiment in 1921.

Time and Depth of Irrigation

The first irrigation was given two to four weeks after the rice had emerged, the time depending upon the amount of rainfall. Usually a four-inch irrigation was given about four weeks after the rice came up to a good stand. No additional water was applied until the water had diminished to about an inch deep on the plats. Then the water was turned on to a depth of 3 to 4 inches and gradually increased at each succes-

sive irrigation until a depth of 6 inches was obtained at the end of the season. The water was not drained off the field until the heads of the rice had turned down, at which time it was drained off to permit the land to dry for harvesting.

EXPERIMENTAL DATA

The studies on fertilizers for rice consisted of two distinct phases: (a) experiments in which different fertilizers were used to determine the best kinds and amounts of fertilizers, and (b) experiments in which the fertilizers were applied at different dates to determine the optimum time (stage of growth of rice) of applying fertilizers. The former were conducted during the whole period of the experiment from 1915 to 1928, inclusive, while the latter have been conducted since 1922.

Results Secured with Different Fertilizers

The results of experiments with different fertilizers are given in Table 2. During the earlier years of the experiment the fertilizers were applied when the rice was planted. Since 1924, however, the fertilizers have been applied about six weeks after planting. The application of 100 pounds of sulphate of ammonia per acre made the largest average yield during the thirteen years of the experiment, during the six years 1915 to 1921, and during the eight-year period, 1915 to 1923. This treatment made an average yield of 2,353 pounds of rough rice per acre during the thirteen years, which was 553 pounds, or 30.7 per cent more than the yield of rice on unfertlized land. The treatment also increased the yield of rice 38.5 per cent and 41.6 per cent during the eight years and six years, respectively. As will be shown later, the treatment of 100 pounds of sulphate of ammonia was the most profitable treatment used.

The treatment consisting of 300 pounds of superphosphate and 200 pounds of sulphate of ammonia per acre produced the second largest average yield for the thirteen years, for the eight years, and for the six years.

The application of 150 pounds of superphosphate and 100 pounds of sulphate of ammonia made the third highest yield of rice in the thirteen-year average, in the eight-year average, and in the six-year average.

An application of 6 tons of manure per acre was included in the experiment from 1915 to 1921, inclusive. During this period it was the only treatment that did not produce a larger average yield than land which received no fertilizer, and for this reason the treatment was discontinued.

Cottonseed meal did not give as good results as sulphate of ammonia, although it made considerably larger average yields than manure.

In 1924, the fertilizer work was expanded to include several rates of application of sulphate of ammonia and of superphosphate to determine the effect of larger amounts of these materials on the yields of

Table 2.—Yields per acre of rice resulting from different fertilizer treatments, 1915 to 1928.

Treatment															Average for			
Lbs. per acre	Material	1915	1916	1917	1918	1920	1921	1922	1923	1924	1925	1926	1927	1928	Six years, 1915-1921	Eight years, 1915-1923	Thirteen years, 1915-1928	Five years, 1924-1928
	No treatment	Lbs. 991	Lbs. 1965	Lbs. 1095	Lbs. 2055	Lbs. 1452	Lbs. 3093	Lbs. 2159	Lbs. 1350	Lbs. 2673	Lbs. 1518	Lbs. 1711	Lbs. 1363	Lbs. 1973	Lbs. 1775	Lbs. 1770	Lbs. 1800	Lbs. 1848
50	Sulphate of ammonia	....	....	....	....	....	*	*	....	....	2765	1925	1828	1566	2211	.....	.....	.....	2059
100	Sulphate of ammonia	1648	1942	2060	2415	3360	3659	2615	1917	2764	1749	2274	1738	2442	2514	2452	2353	2193
200	Sulphate of ammonia	....	....	....	....	....	....	....	....	2974	2024	1850	1689	2646	.....	.....	.....	2237
75	Superphosphate	....	....	....	....	....	....	....	....	2759	1810	1982	1362	2068	.....	.....	.....	1996
150	Superphosphate	1776	1558	1417	2960	2299	2831	2089	1307	2708	1678	2200	1576	2197	2140	2030	2039	2054
300	Superphosphate	....	....	....	....	....	....	....	....	2319	1639	1815	1489	1837	.....	.....	.....	1820
50 75	Sulphate of ammonia, Superphosphate	1223	1950	1930	2970	2057	2831	2373	1416	2768	1942	2131	1522	2052	2160	2094	2090	2083
100 150	Sulphate of ammonia, Superphosphate	1839	1820	1520	2800	2662	3456	2093	1699	2943	1656	2390	1451	2371	2350	2236	2208	2162
200 300	Sulphate of ammonia, Superphosphate	2188	1940	1160	2741	2833	4158	2703	1742	2885	1705	1929	1624	2272	2503	2433	2298	2083
300	Cottonseed meal	1854	1811	1770	2756	1815	2773	2425	1394	....	....	....	....	....	2130	2075	.....	.....
300 150	Cottonseed meal, Superphosphate	1614	1890	1430	2560	1794	2083	2173	1263	....	....	....	....	....	2062	1976	.....	.....
12000	Manure	1682	1209	982	2630	968	2856	....	....	....	....	....	....	....	1721	.....	.....	.....
12000 150	Manure, Superphosphate	1682	1603	1002	2745	1815	2865	....	....	....	....	....	....	....	1952	.....	.....	.....
300 200 100	Superphosphate, Sulphate of ammonia, Sulphate of potash	....	....	....	....	....	....	....	....	2515	1584	2730	2123	3234	.....	.....	.....	2437
300 100	Superphosphate, Sulphate of potash	....	....	....	....	....	....	....	....	2909	1452	2609	1659	2657	.....	.....	.....	2257
200 100	Sulphate of ammonia, Sulphate of potash	....	....	....	....	....	....	....	....	1957	1369	2247	2336	1947	.....	.....	.....	1971
100	Sulphate of potash	....	....	....	....	....	....	....	....	2713	1353	2112	1271	1634	.....	.....	.....	1817

*150 pounds in 1920 and 1921.

rice. The use of potash alone and in combination with sulphate of ammonia and superphosphate was included also. The average yields of rice obtained from the several fertilizer treatments during the five years, 1924 to 1928, inclusive, are given in the last column of Table 2. The yield of rice increased as the amount of sulphate of ammonia was increased, but the increase in yield was not directly proportional to the amount of sulphate of ammonia applied.

Superphosphate was applied at the rate of 150 pounds per acre during the period of the experiment and at the rates of 75, 150, and 300 pounds per acre during the last five years, 1924 to 1928. The application of 150 pounds per acre made the largest average yield, 2,054 pounds per acre, or 206 pounds more than the yield of untreated soil during the five years.

The combination of 300 pounds of superphosphate and 200 pounds of sulphate of ammonia did not produce as large an average yield as the application of 200 pounds of sulphate of ammonia.

During the last five years, 1924 to 1928, inclusive, the largest average yield, 2,437 pounds of rough rice per acre, resulted from the use of a complete fertilizer consisting of 300 pounds of superphosphate, 200 pounds of sulphate of ammonia, and 100 pounds of sulphate of potash per acre. This treatment made an increase of 589 pounds, or 31.8 per cent, over the yield of the soil which received no fertilizer treatment. The increase in yield, however, was not profitable, as will be shown later (Table 4).

Potash when used alone did not increase the yield of rice, but when it was applied along with superphosphate increase in yield resulted.

During the thirteen years of the experiment, the application of sulphate of ammonia at the rate of 100 pounds per acre made an average increase of 553 pounds of rice per acre, which was an increase of about 27 pounds of rice for each pound of nitrogen applied. (One hundred pounds of sulphate of ammonia contains 20 pounds of nitrogen.) For the last five years, however, the average increase was only 17 pounds of rice per acre for each pound of nitrogen applied.

The results given in Table 2 show that the soil responded to both nitrogen and phosphoric acid, but nitrogen gave larger increases in yield than phosphoric acid, indicating that nitrogen is needed more than phosphoric acid for the production of rice. The application of 100 pounds of sulphate of ammonia per acre was the best treatment used when both yield and profit are considered.

Time of Application of Fertilizers

Observations made during the course of the experiments reported in Table 2 seemed to indicate that the application of fertilizers, especially phosphoric acid, at planting time was beneficial to weeds at the expense of the rice crop. It was noted that the growth of weeds was more abundant on plats which received fertilizer than it was on un-

fertilized land. In 1917, it was observed that the weed growth was greatest on the plats which received the largest amounts of fertilizers and that the yields of rice apparently decreased as the rate of fertilizer increased, due to the excessive growth of weeds. Subsequent work in other parts of the world has shown that applications of fertilizers after the rice has been planted give larger yields than applications of fertilizers at planting time.

The Louisiana Agricultural Experiment Station (Thirty-fifth Annual Report, 1915), in reporting the results of fertilizer work which included phosphoric acid, stated: "A serious difficulty, however, to be contended in continuous cropping is that the application of acid phosphate accelerates the growth of grasses and weeds until these field pests become a menace to the crop."

In fertilizer experiments with rice in the Dutch East Indies (Experiment Station Record 45:622), multiple or fractional applications of superphosphate and of sulphate of ammonia were more profitable than the same amount applied at one application.

The United States Department of Agriculture carried on some work with rice in California in which fertilizer was applied (a) when the rice plants were 3 inches high, (b) when the first heads were appearing, and (c) two weeks after first heading. The results of this work were published in United States Department of Agriculture Bulletin 1155. The application of fertilizer when the plants were 3 inches high produced considerably larger yields than later applications. As an average of the three years, 1917, 1918, and 1919, fertilizer applied when the plants were 3 inches high produced 226 pounds of rice per acre more than the fertilizer applied when the first heads appeared, and 424 pounds per acre more than the fertilizer applied two weeks after first heading.

It seemed desirable, therefore, to conduct experiments to determine the optimum time of applying fertilizers to rice under conditions prevailing in Texas. Accordingly, an experiment was outlined in 1922 with the view of obtaining the desired information. Previous work (Table 2) had shown that 100 pounds of sulphate of ammonia per acre was one of the best fertilizer treatments used. This treatment and 150 pounds of superphosphate were used alone and in combination in the work on time of application of fertilizers.

In 1922, these treatments were made at planting time and 12 weeks after planting. Since 1922, the fertilizers have been applied when the rice was planted, 6 weeks after planting, 12 weeks after planting, and in fractional applications in which one-third of the fertilizer was applied at planting time, one-third 6 weeks after planting, and one-third 12 weeks after planting.

The results obtained in conducting the work involving dates of application of fertilizers are given in Table 3. During the six years, 1923 to 1928, inclusive, the application of fertilizers 6 weeks after

planting made larger yields than applications made at other dates. There was not, however, very much difference in the yields of rice resulting from the four dates of application of 100 pounds of sulphate of ammonia.

The application of superphosphate 6 weeks after planting made an average yield of 254 pounds more per acre than the application made at planting time. The treatment of 100 pounds of sulphate of ammonia and 150 pounds of superphosphate applied six weeks after planting made an average yield of 374 pounds of rice per acre more than the treatment applied at planting time. These increases in yield are sufficient to justify the expense of applying the superphosphate at a separate operation and indicate that if phosphoric acid is used alone or with sulphate of ammonia, it should be applied about 6 weeks after planting.

Table 3.—Yield per acre of rice fertilized at different dates.

Year	Time of applying	None	100 lbs. sulphate of ammonia	150 lbs. superphosphate	100 lbs. sulphate of ammonia, 150 lbs. superphosphate
		Lbs.	Lbs.	Lbs.	Lbs.
1922	When rice was planted	2159	2615	2089	2093
	12 weeks after planting		2544	2026	2343
1923	When rice was planted	1307	1459	1416	1350
	6 weeks after planting		1742	2134	1830
	12 weeks after planting		1982	1634	1830
	Fractional application*		1307	1437	1307
1924	When rice was planted	2420	2741	2554	2526
	6 weeks after planting		3042	2741	2253
	12 weeks after planting		2528	2446	2775
	Fractional application*		2866	2610	2627
1925	When rice was planted	1379	1639	1144	1205
	6 weeks after planting		1774	1329	1865
	12 weeks after planting		1425	1287	1474
	Fractional application*		1529	1221	1089
1926	When rice was planted	1963	2602	2222	2092
	6 weeks after planting		2274	2200	2390
	12 weeks after planting		2360	2257	1867
	Fractional application*		2297	2223	2332
1927	When rice was planted	1821	1893	1501	1729
	6 weeks after planting		2112	1984	1977
	12 weeks after planting		2123	1803	2033
	Fractional application*		2053	1591	1785
1928	When rice was planted	2103	2371	2178	1956
	6 weeks after planting		2352	2151	2789
	12 weeks after planting		2712	2437	2690
	Fractional application*		2789	2365	2657
Av. 1922 to 1928	When rice was planted	1879	2189	1872	1850
	12 weeks after planting		2239	1984	2145
Av. 1923 to 1928	When rice was planted	1832	2118	1836	1810
	6 weeks after planting		2216	2090	2184
	12 weeks after planting		2188	1977	2112
	Fractional application*		2140	1908	1966

*One-third of fertilizer applied at planting time, one-third six weeks after planting, and one-third twelve weeks after planting.

Fractional application of the fertilizer made larger average yields than application made at planting time. When the three treatments are considered together, the fractional application made an average yield of 2,005 pounds of rough rice per acre, or only 84 pounds more per acre than the application made at planting. This small increase probably would not justify the expense involved in making the fractional applications.

The results on time of application of fertilizers show that if sulphate of ammonia is used alone, it should be applied when the rice is planted, since the increase in yield from later applications probably would not justify the additional expense of applying the fertilizer at a separate operation. If superphosphate is used alone or in combination with sulphate of ammonia, probably it should be applied about six weeks after planting the rice because the increase in yield obtained by applying the treatment at that time was large enough to offset the expense of applying the fertilizer at a separate operation and still leave a substantial profit. Where fertilizers containing sulphate of ammonia are applied after planting, care should be taken to make the application when the plants are dry, because the sulphate of ammonia may burn the plants if applied when they are wet.

PROFITS OBTAINED FROM THE USE OF FERTILIZERS

The best fertilizer to use on rice or any other crop is the one that will give the largest profit over a period of years. The fertilizers that produce the largest increases in yield are not always the most profitable. The yields of rice produced by the various fertilizer treatments have been discussed (Table 2), but the yields alone do not necessarily reveal the most suitable or most profitable treatment to use in farm practice. When the cost of the fertilizers and the prices of rice are known, however, one can readily determine the most profitable treatment.

The profits and losses resulting from the use of fertilizers on rice at the Experiment Station, Beaumont, Texas, are given in Table 4. The profits and losses were obtained by deducting the cost of fertilizers from the value of the increase produced by the fertilizers and do not take into consideration the expense involved in applying the fertilizer and harvesting and threshing the increase produced by the fertilizers. The wholesale price of rice ranged from $2.17 to $2.78 per 100 pounds during the last five years and the average price was $2.46 per 100 pounds, but for the purpose of calculating the profits here the price of $2.45 was used. The average retail prices of fertilizer materials per ton used during the five years, 1924 to 1928, were: sulphate of ammonia, $77.40; superphosphate (16 per cent), $22.35; and muriate of potash, $53.35. Sulphate of potash was used in the work but since it is not readily obtainable on the market and retail prices are not at

Table 4.—Increase in yield of rice per acre and profit obtained from use of fertilizers at Beaumont, Texas.

Treatment, pounds per acre	For the 13 years, 1915-1928				For the 5 years, 1924-1928			
	Increase in yield due to fertilizer	Value at $2.45 per 100 lbs.	Cost of fertilizer	Net gain	Increase in yield due to fertilizer	Value at $2.45 per 100 lbs.	Cost of fertilizer	Net gain
	Lbs.				Lbs.			
50 Sulphate of ammonia	.....	.....	.....	.....	211	$ 5.17	$ 1.95	$ 3.22
100 Sulphate of ammonia	553	$ 13.55	$ 3.90	$ 9.65	345	8.45	3.90	4.55
200 Sulphate of ammonia	.....	.....	.....	.....	389	9.53	7.80	1.73
75 Superphosphate	.....	.....	.....	.....	148	3.63	0.85	2.78
150 Superphosphate	239	5.86	1.70	4.16	206	5.05	1.70	3.35
300 Superphosphate	.....	.....	.....	.....	—28	.....	3.40	—3.40*
50 Sulphate of ammonia, 75 Superphosphate	290	7.11	2.80	4.31	235	5.76	2.80	2.96
100 Sulphate of ammonia, 150 Superphosphate	408	10.00	5.60	4.40	314	7.69	5.60	2.09
200 Sulphate of ammonia, 300 Superphosphate	498	12.20	11.20	1.00	235	5.76	11.20	—5.44
100 Sulphate of potash	.....	.....	.....	.....	—31	.....	2.65	—2.65
200 Sulphate of ammonia, 100 Sulphate of potash	.....	.....	.....	.....	123	3.01	10.45	—7.44
300 Superphosphate, 100 Sulphate of potash	.....	.....	.....	.....	409	10.02	6.05	3.97
200 Sulphate of ammonia, 300 Superphosphate, 100 Sulphate of potash	.....	.....	.....	.....	589	14.43	13.85	0.58

*The minus sign (—) indicates a loss.

hand, the price of muriate of potash, which may be bought on most markets, was used in calculating the profits from the use of potash.

The treatment of 100 pounds of sulphate of ammonia per acre made an average increase in yield of 553 pounds of rough rice per acre during the thirteen years of the experiment and 345 pounds per acre for the last five years. The profit to be derived from such increase in yield would, of course, depend upon the prices received for the rice and prices paid for the fertilizer, but on the basis of the figures given in the preceding paragraph, the treatment made an average annual profit of $9.65 per acre for the thirteen years and $4.55 per acre during the last five years. This was the most profitable treatment used in both periods of years.

During the thirteen years of the experiment, the treatments of (a) 150 pounds of superphosphate, (b) 50 pounds of sulphate of ammonia and 75 pounds of superphosphate, and (c) 100 pounds of sulphate of ammonia and 150 pounds of superphosphate were almost equally profitable, each making an average profit of slightly more than four dollars per acre a year. While the treatment of 200 pounds of sulphate of ammonia and 300 pounds of superphosphate made an average increase of 498 pounds of rice per acre, it made an average profit of only $1.00 per acre a year.

Considering now the results for the five years, 1924 to 1928, inclusive, it will be observed that the application of 100 pounds of sulphate of ammonia per acre made the largest average profit, $4.55 per acre (Table 4). The treatment consisting of 300 pounds of superphosphate and 100 pounds of sulphate of potash made the second largest increase in yield, 409 pounds per acre, and the second greatest profit, $3.97 per acre a year.

The treatment of 50 pounds of sulphate of ammonia and the treatment of 150 pounds of superphosphate made about the same average increases in yield, 211 and 206 pounds of rice per acre, respectively, and practically the same average profit, $3.22 and $3.35 per acre annually.

The complete fertilizer consisting of 200 pounds of sulphate of ammonia, 300 pounds of superphosphate, and 100 pounds of sulphate of potash, produced the largest average increase, 589 pounds of rice per acre, which, however, resulted in an average profit of only $0.58 per acre a year. The treatment was used at a considerable loss two of the five years, but the profit during the other three years was sufficient to offset this loss.

Four treatments: (1) 300 pounds of superphosphate, (2) 200 pounds of sulphate of ammonia and 300 pounds of superphosphate, (3) 100 pounds of sulphate of potash, and (4) 200 pounds of sulphate of ammonia and 100 pounds of sulphate of potash were unprofitable, the losses ranging from $2.65 to $7.44 per acre a year for the five years.

The results in Table 4 show rather conclusively that sulphate of

ammonia was the most profitable treatment used in the experiment. The use of (1) 300 pounds of superphosphate and 100 pounds of sulphate of potash, (2) 150 pounds of superphosphate, and (3) 50 pounds of sulphate of ammonia, however, made substantial profits.

DISCUSSION OF RESULTS

Sulphate of ammonia was a better source of nitrogen than cottonseed meal or manure in the experiments at Beaumont, Texas. The use of 100 pounds per acre of sulphate of ammonia was the most profitable treatment used in the experiment. These results are in general agreement with the results of fertilizer experiments on rice in other parts of the world. For example, in experiments conducted at Biggs, California, by the United States Department of Agriculture, sulphate of ammonia was one of the most profitable fertilizers used. The California Agricultural Experiment Station also obtained excellent results with sulphate of ammonia. Similar results were obtained in experiments conducted in Guam, Hawaii, and India.

In work on the time of application of fertilizers, applications made after the rice was planted gave larger average yields than applications made at planting time. The largest yield resulted from fertilizers applied six weeks after the rice was planted. These results are in accord with the results of somewhat similar work done in California by the United States Department of Agriculture, in which fertilizer applied when the rice was three inches high produced larger yields than fertilizer applied at later stages of growth.

Fractional applications of fertilizers in which one-third of the fertilizer was applied when the rice was planted, one-third 6 weeks after planting, and the remaining one-third 12 weeks after planting made larger yields than single applications made at planting time. The fractional application of fertilizer, however, made smaller average yields of rice than single applications made 6 weeks and 12 weeks after planting. Somewhat similar results have been reported from the Dutch East Indies (Experiment Station Record 45:622).

SUMMARY

Applications of sulphate of ammonia made larger increases in yield than superphosphate. Treatments consisting of sulphate of ammonia and superphosphate did not produce larger yields than treatments of sulphate of ammonia alone, indicating that the soils are more deficient in nitrogen than phosphoric acid for the production of rice.

Sulphate of ammonia was used alone at the rates of 50, 100, and 200 pounds per acre. The yield of rice increased as the rate of sulphate of ammonia was increased, but the yield was not proportional to the increase in the rate of sulphate of ammonia. Sulphate of ammonia applied at the rate of 100 pounds per acre produced an average increase of 553 pounds of rice per acre over the check plats and was

the most profitable treatment, returning an average profit of $9.65 per acre for thirteen years. During the last five years of the experiment this treatment produced an average increase of only 345 pounds of rice per acre, resulting in a profit of $4.55 per acre.

Superphosphate applied at the rate of 150 pounds per acre made larger increases in yield of rice than applications of 75 pounds and 300 pounds per acre. The 150-pound rate produced an average increase of 239 pounds of rice, or 14.3 per cent, over the yield of rice on the unfertilized soil. This treatment was more profitable than the other treatments of superphosphate and gave a yearly profit of $4.16 per acre for the thirteen years.

The use of potash alone did not increase the yield of rice, but when used with superphosphate or with sulphate of ammonia and superphosphate it produced significant increases in yield. During the five years 1924 to 1928, the combination of 300 pounds of superphosphate and 100 pounds of sulphate of potash per acre made the second largest profit, $3.97 per acre annually.

In the work on time of application of fertilizers, applications made six weeks after planting the rice gave larger average yields than fertilizers applied at planting time, 12 weeks after planting, or fractional applications in which one-third of the fertilizer was applied at planting time, one-third 6 weeks after planting, and one-third 12 weeks after planting. While the application of fertilizers after planting made larger yields than applications made at planting time, the increase in yield in the case of sulphate of ammonia probably would not justify the additional expense of applying the fertilizers at a separate operation. Where superphosphate was used alone or with sulphate of ammonia, the increase resulting from applications made six weeks after planting were large enough to be profitable.

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