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Research On Rice Production in Texas

in cooperation with the
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TEXAS AGRICULTURAL EXPERIMENT STATION

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Outfield work was done in cooperation with county agricultural agents and individual rice grower in the respective counties.

Many of the photographs used were obtained from L. E. Stagg, Jr., Beaumont. The cover photograp is by Air-View, Beaumont.

THE COVER PICTURE

Texas Gulf Coast farmers compare growth characteristics of different varieties of rice during a field day on the Rice-Pasture Experiment Station near Beaumont.

In the immediate foreground are research plots which show the response of rice to various fertilizer treatments. The land in the background is planted to forage legumes.

The land is used in a 3-year rotation system, one year in rice and two years in forage legumes. Of the 600 acres in the station, about 200 acres are planted to rice each year.

DIGEST

This bulletin reports some of the studies conducted on rice production by the Rice-Pasture Experiment Station, Beaumont, Texas, during the past 10 years. These include the development and testing of new and superior varieties of rice; time, methods and rates of seeding; time, methods and rates of application of fertilizers; studies on irrigation; control of weeds, insects and diseases; and drying and storing rough rice.

Bluebonnet, Bluebonnet 50, Improved Bluebonnet, Century Patna, Texas Patna and TP 49 are the more important varieties developed in the rice improvement program in Texas. These are long-grain varieties and, together with Rexoro, comprise over 90 percent of the rice production in the State. They yield and mill well and have reasonably good table quality.

Experiments indicate that the optimum rate of seeding is about 90 pounds per acre.

Early-maturing varieties yielded equally well whether seeded in March or June. The average yield of the midseason varieties, however, decreased markedly as seeding was delayed. The average yield of the late-maturing varieties also decreased sharply as seeding was delayed, and the late seeding did not mature. Midseason and late-maturing varieties should be seeded as early as practicable to insure satisfactory yields.

Applications of 80 pounds of nitrogen and 40 pounds of phosphoric acid per acre (80-40-0) gave better results than other fertilizers on Beaumont clay, Lake Charles clay and Lake Charles clay loam, and are recommended for these soils. The use of 40-40-20 is recommended for Katy fine sandy loam.

Sulfate of ammonia, urea and cyanamid were better sources of nitrogen for rice than nitrate of soda.

Varieties of rice of different maturity responded differently to dates of application of fertilizers. Where early and midseason varieties are to be grown on land relatively free of weeds, all of the fertilizer could be applied at seeding, or at any time up to 40 days after seeding, with very little difference in yield. Where these varieties are grown on land badly infested with weeds, all of the fertilizer should be applied as a top-dressing 35 to 40 days after seeding. Where late varieties are grown, all of the fertilizer should be applied as a top-dressing 30 to 40 days after seeding.

The use of 45 to 50 inches of water for irrigation produced as large a yield of rice as larger amounts of water. Draining rice fields once during the season increased the yield of rice considerably.

Rice stinkbugs were controlled by spraying with the following chemicals at the rates per acre indicated: aldrin, 0.5 pound; dieldrin, 0.25 pound; DDT, 1.0 pound; and toxaphene, 1.5 pounds. The rice water weevil was controlled by spraying with DDT at the rate of 1 pound per acre and with potosan at 14 ounces per acre. Grasshoppers were controlled by spraying with toxaphene, chlordane, aldrin or dieldrin. Armyworms were controlled by toxaphene.

Suitable cultural practices and the judicious use of water are, at present, the most practical means of controlling both grasses and broad-leaf weeds in rice fields. Summer or fall plowing, with several diskings timed to kill weed seedlings before planting rice, is a basic step in getting clean stands of rice. If cultural practices are not feasible, chemical control may be used. Formulations of 2,4-D or 2,4,5-T, applied in accordance with State laws, can be used in the control of weeds in rice fields.

Rough rice was dried at air temperatures of 115 to 125° F. in a commercial column-type dryer without lowering the milling quality, grade or germination. Rice with initial moisture contents ranging from 15.9 to 21.1 percent stored in 500 and 600-barrel bins was dried with unheated air supplied at rates of 6 to 11 cubic feet per minute (cfm) per barrel. A tunnel-type dryer was well suited for drying seed rice in bags.

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Research On Rice Production In Texas

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ALTHOUGH RICE WAS GROWN IN TEXAS on a small scale as early as 1863, the crop was of little commercial importance prior to 1900 (34, 48). It is now one of the more important field crops in Texas, ranking fifth in acreage. Rice was grown on 574,000 acres in the State in 1953 and on an average of 456,000 acres for the 10 years, 1942-51, according to reports of the U. S. Department of Agriculture (45). Texas is the leading rice state and produced 28.52 percent of the United States rice crop in 1952. It ranks second in rice acreage.

Rice growing is concentrated in the southeastern part of the State, known as the Gulf Coast Prairie, Figure 1. The crop is grown mostly in 15 counties, although small acreages occur in a few counties outside of that area. Data on yield, acreage and production by counties have been reported recently by Bonnen and Gabbard (7).

The State of Texas established an experiment station near Beaumont in 1909 for the purpose of studying and solving some of the problems encountered in rice production. From 1912 to 1914, it was known as the Cooperative Rice Experiment Station. In 1914, it became Substation No. 4 of the Texas Agricultural Experiment Station. In 1946, the station was moved from near Beaumont to the Pine Island community about 10 miles west of Beaumont on U. S. highway 90 to provide better facilities for expanding research on rice production and other phases of agriculture associated with rice growing, especially forage crops, pastures and beef cattle production. It is now known as the Rice-Pasture Experiment Station.

In Texas, rice does not produce satisfactory yields when grown on the same land every year for long consecutive periods. For this reason, it is usually grown on land 1 to 3 years and then changed to new land or land that has not been in rice for several years. Old rice fields are grazed by cattle or are allowed to lie idle. Since rice land is high in value it is more profitable to pasture old rice fields and get some income from cattle grazing. Thus, rice growing and beef cattle production are closely associated.

Some of the earlier work at the Rice-Pasture Experiment Station has been published in bulletins, progress reports and annual reports of the Texas Agricultural Experiment Station. This bulletin reports results of some of the more recent experiments on rice production.

CLIMATIC, SOIL AND WATER REQUIREMENTS OF RICE

Climatic Adaptation

Rice is grown mainly in tropical and subtropical regions, although it is produced to some extent in temperate regions. For successful production, rice requires high temperatures, especially high average temperatures, during the growing season; an adequate and dependable supply of fresh water for irrigation; comparatively level soils that hold water well because of their slowly permeable surface or subsoils through which loss of water by percolation is small; and good surface drainage.

These requirements are found in the coastal prairies of Southeast Texas and Southwest Louisiana, the Grand Prairie and other areas in Eastern Arkansas, and elsewhere in the South-central States and in the valleys of Central California. In Texas, the rice belt extends from the Sabine River on the east to the San Antonio River on the west. This region has a warm, sultry, summer climate, with an average yearly rainfall of about 54 inches at Beaumont in the eastern part and which diminishes to about 36 inches at Victoria in the western part.

Soils

Rice grows well on many kinds of soil, but usually produces larger yields on heavier types (fine-textured) of soil, such as silt loams and clays, with slowly or very slowly permeable subsoils. Soils with these characteristics have a definite advantage in growing rice because they prevent excessive percolation of water through the subsoil and are conducive to the most efficient use of irrigation water.

Lake Charles clay and Beaumont clay are the most important rice soils in Texas. Rice also is grown extensively on Lake Charles clay loam, Hockley fine sandy loam, Katy fine sandy loam and Edna fine sandy loam. All of these soils are favorable for rice production. They are comparatively level and, in general, have fairly good surface drainage.

Sources of Irrigation Water

Irrigation water for rice is obtained from the larger streams of the area and from wells. The Neches, Sabine, Trinity, Brazos and Colorado Rivers are the main sources of water for irrigating rice. In the Katy and Hockley areas, and some other areas, irrigation water is obtained from wells. Rainfall, of course, is another source

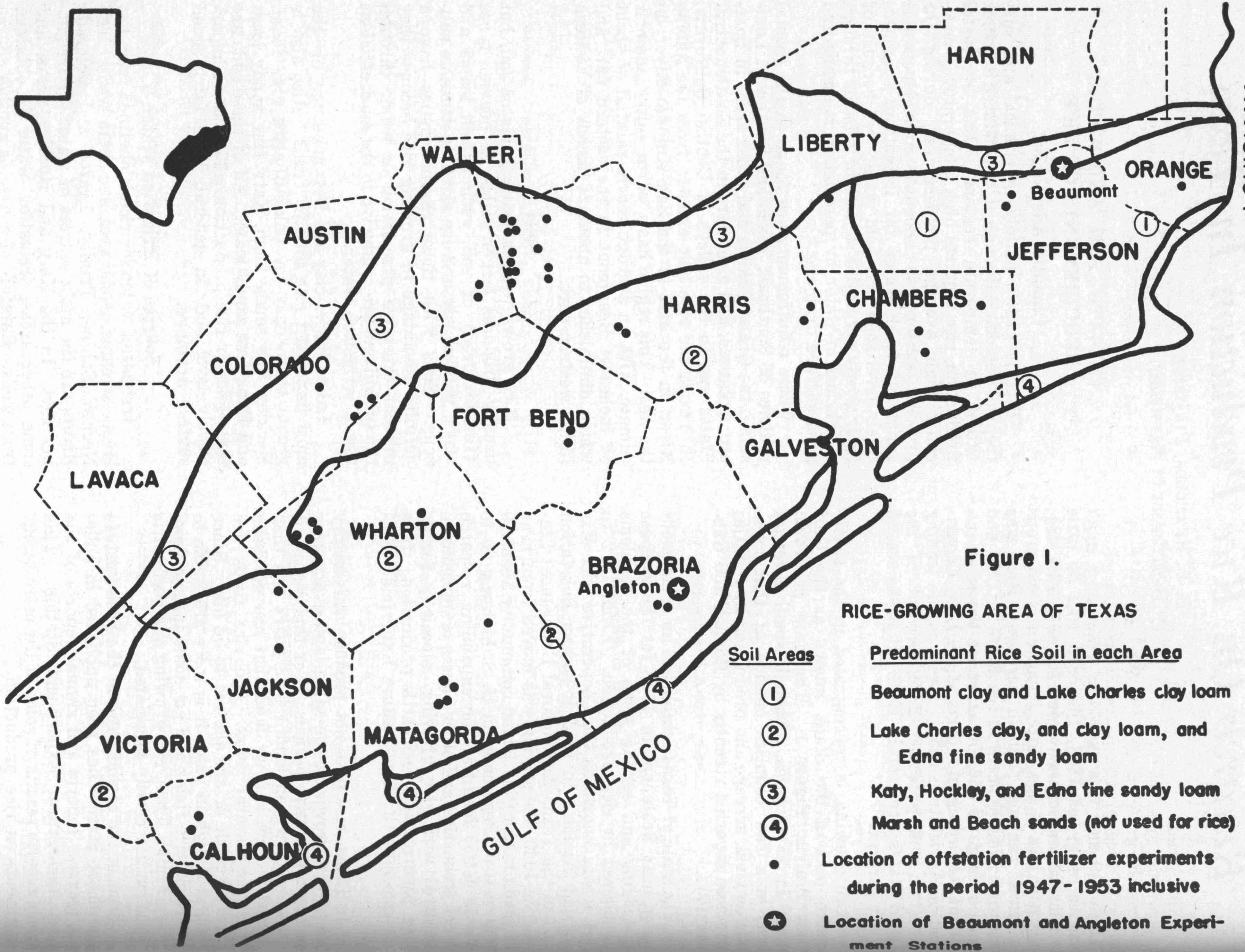

Figure I.

RICE-GROWING AREA OF TEXAS

of water for rice. Although large areas of soils are suitable for growing rice, some are not accessible to available sources of water.

CROPPING SYSTEMS

High yields of rice have not been sustained by growing rice on the same land every year. Nor has the growing of cultivated crops in rotation with rice proved practical in most of the Texas rice belt. This has resulted in the common practice of growing rice 1 to 2 years followed by 2 to several years of grazing beef cattle on vegetation volunteering between rice crops. Sometimes the land has been left idle for the 2 to several years between rice crops. The physical condition and the organic matter content of the soil and rice yields were improved by these practices.

The Beaumont station began research on rotations and cropping systems in 1913 to determine better systems of cropping. Investigations during 1931-45 included rice in 1, 2 and 4-year rotations. During the 11 years, 1931-41, rice was grown continuously; continuously with fall-seeded *Melilotus indica* (sour clover); and in 2-year rotations with idle land, summer fallow, cotton, soybeans, sesbania and crotalaria. Average yields were 1,072 pounds per acre for continuous rice and 1,194 for continuous rice with fall-seeded *Melilotus indica.* Average yields in the 2-year rotations were 1,613 pounds per acre for rice and idle land, 1,635 for rice and summer fallow, 1,707 for rice and cotton, 1,618 for rice and soybeans, 1,725 for rice and sesbania and 1,642 for rice and crotalaria. The use of other crops did not increase rice yields in either the 1 or 2-year rotations.

Studies from 1943 to 1945 indicated that rotations of Alyce clover and rice were more satisfactory. Yields of rice following Alyce clover ranged from 2,500 to 2,860 pounds per acre, as compared with 1,800 pounds for rice not following Alyce clover.

This work and the need for better pastures for beef cattle on rice farms led to investigations started in 1946 on the rapid, low-cost conversion from rice to improved pasture in rice-pasture systems of farming.

It was found practical to convert from rice to pasture by broadcasting grass and clover seed, without seedbed preparation, in standing rice at the last draining, about 10 days before harvest, and in rice stubble after harvest (30). The best time to seed the grass-clover mixtures was between October 15 and December 1. Broadcasting seed and fertilizer can be done from ground or air equipment. The levees and drainage ditches used to irrigate and drain the rice crop are used to provide drainage and irrigation systems for the pastures. A mixture of Dallisgrass and clover (Louisiana white, Persian and large hop) was successful in the more humid areas. Hubam clover was a more satisfactory legume in most of drier areas. Bermudagrass can be seeded in all areas but, generally, this is unnecessary as it usually volunteers following rice. Ryegrass, tall fescue and cereals were seeded with success in standing rice at last draining and in rice stubble. Lespedeza was established by broadcasting the seed in rice stubble in late February or early March.

Annual beef gains of 200 pounds per acre are possible from improved pastures, as compared with less than 50 pounds for unseeded, unfertilized pasture fields. Rice yields following improved pastures increased 20 percent or more. The clovers and Bermudagrass and sometime Dallisgrass volunteer after the rice crop to provide the grasses and legumes for the next pasture period. Pasture seed and hay may be harvested from these fields.

The several possible rice-pasture systems of farming have not been fully evaluated. However, such systems as 2 years rice, 3 years pasture; 2 or 3 years rice, several years pasture; 1 year rice, 2 to 3 years pasture seem to be worth considering in systems to maintain and improve soil tilth and productivity between rice crops, as well as for providing year-long grazing of nutritious forage for beef cattle on rice farms.

PREPARATION OF THE SEEDBED

The main purpose of preparing a seedbed for rice is to obtain a good, mellow surface layer that will be favorable for seeding, germination of the seed and growth of the young rice plants, and to destroy weeds. The soil usually is plowed 3 to 4 inches deep. Early experiments on time and depth of plowing at the Beaumont station (28) indicated that soil plowed 5 to 8 inches deep in the fall or spring produced somewhat larger yields of rice than soil plowed 2 inches deep. There was not much difference in yield from fall and spring plowing. Summer, fall or early winter plowing, however, has some advantage over spring plowing because it distributes labor over longer periods. Land plowed in the fall forms a better tilth and is easier to prepare for seeding by disking and harrowing than land plowed in the spring.

Rice land is generally plowed with heavy disk or moldboard plows, depending on the condition of the soil. Disk plows generally are used when the soil is dry and hard, Figure 2. Moldboard plows do not perform well in hard, dry soils and, for this reason, are used when the soil is moist and in good condition for plowing.

Rice land may be plowed any time from August until just prior to seeding the following spring, depending on rainfall or the need for the land for pasture or other purpose. Summer plowing frequently is practical on fields infested with red rice or other weeds. Following summer

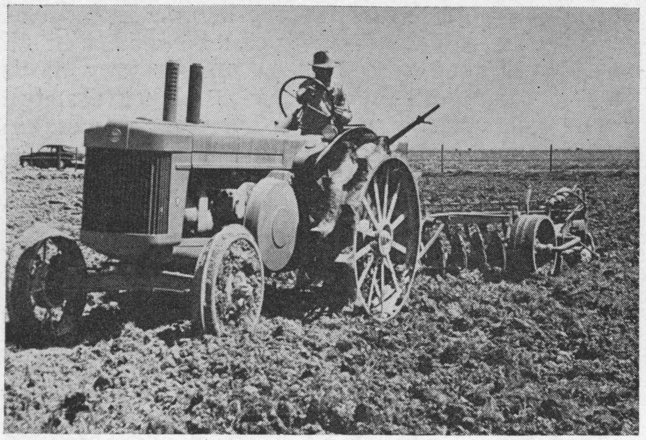

Figure 2. Plowing land for rice with a disk plow.

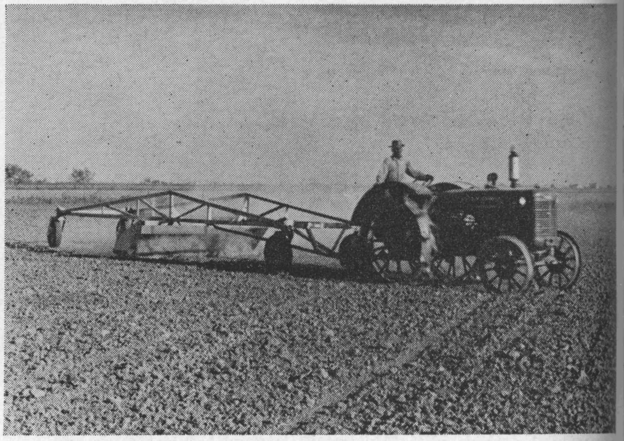

Figure 4. Leveling with a large land leveler.

plowing, the land may be leveled and disked or harrowed as needed for the control of weeds. Land plowed in the fall usually is left rough until spring, then it is disked and harrowed preparatory to seeding, Figure 3.

Drainage furrows should be opened through the fields after the last tillage operation in the fall to provide adequate surface drainage. Many farmers wait until the first heavy rain of the fall when some water is standing on the land to make the drainage furrows. At this time, the natural drainage channels can be located. A small grader or a bedder usually is used for this operation.

Usually it is not necessary to replow in the spring the fields that were plowed the previous summer or fall, except on poorly-drained soil or during seasons of heavy rainfall.

In general, land plowed in the spring should be disked and harrowed as soon as practicable after plowing to break up any large lumps and clods, to prevent baking or crusting and to avoid subsequent difficulty in preparing the seedbed. Experience has shown that heavy soils, such as Beaumont clay and Lake Charles clay, generally require more subsequent tillage, such as disking and harrowing, to obtain a desirable seedbed when plowed in the spring than when plowed in the fall or early winter.

Land leveling with land planes or other land-leveling devices is coming into greater use in Texas, Figure 4. Leveling increases the uniformity of contours between levees and results in better drainage and more uniform depths of water when the land is irrigated. Complete drainage is essential for uniform stands of rice and a uniform depth of irrigation water is essential for the control of weeds.

TYPES AND VARIETIES OF RICE

Exact figures are not available on the acreage planted to different types and varieties in the early years of rice growing in Texas. It is known, in general, that long-grain varieties, such as Honduras, Carolina Gold and similar varieties, were planted first.

From 1920 to 1939, the bulk of the Texas acreage was sown to the medium-grain varieties Early Prolific and Blue Rose, which were developed by Sol Wright of Crowley, Louisiana.

During the past several years, the Texas, Arkansas and Louisiana Agricultural Experiment Stations developed new and superior varieties of

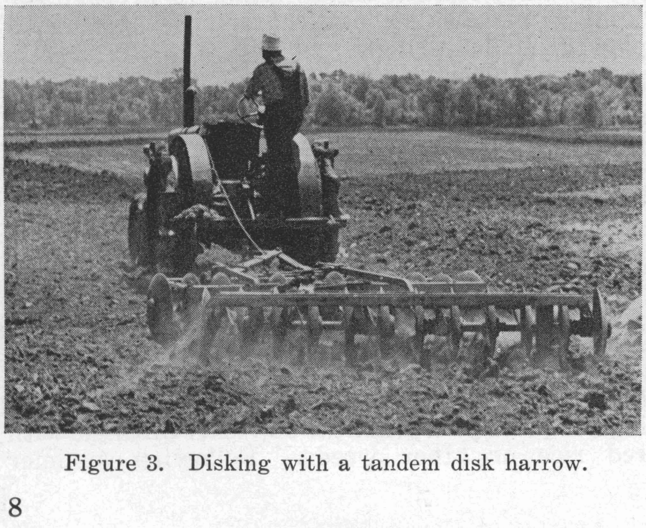

Figure 3. Disking with a tandem disk harrow.

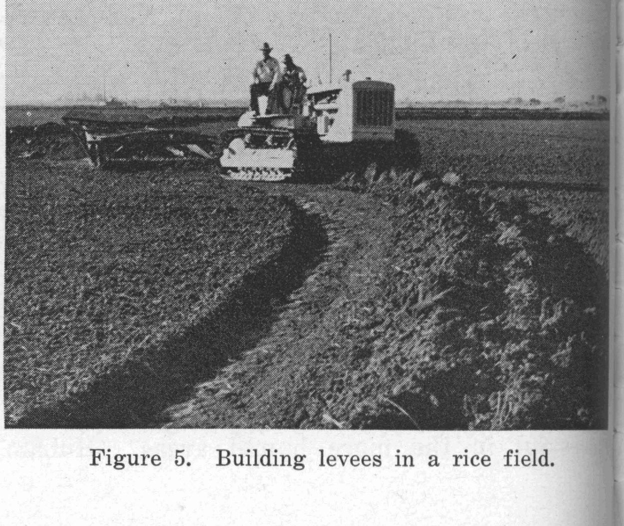

Figure 5. Building levees in a rice field.

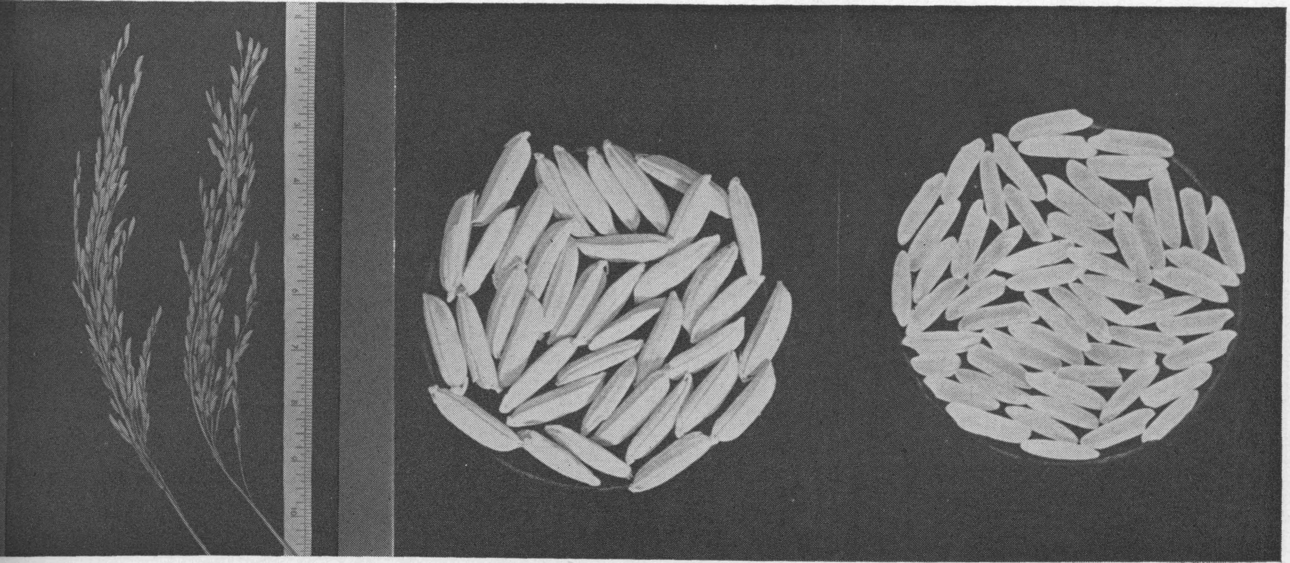

Figure 6. A typical head of Bluebonnet rice, and rough and milled rice.

rice better adapted to combining and artificial drying (23). These now are the principal varieties grow in these states.

Long-grain varieties comprised about 90 percent of the Texas rice production in 1952, and the medium-grain varieties about 7 percent (35).

Types of Rice

Commercial varieties of rice grown in the United States are classified as short-grain, medium-grain and long-grain varieties. Varieties also may be grouped as early, midseason and late, according to the number of days required to reach maturity. In Texas, early-maturing varieties require 109 to 135 days from planting to maturity; midseason-maturing varieties, 125 to 150 days; and late-maturing varieties, 150 to 180 days.

These types, with examples of varieties under each are:

Long-grain varieties: Century Patna 231 (early), Bluebonnet (midseason), Bluebonnet 50 (midseason), Improved Bluebonnet (midseason), Rexoro (late), Texas Patna (late) and TP 49 (late).

Medium-grain varieties: Zenith (early), Magnolia (early) and Blue Rose (midseason).

Short-grain varieties: Acadia (midseason) and Caloro (midseason).

Variety Tests

Many types and varieties of rice have been introduced from the rice-growing countries of the world and tested to determine their adaptation to

Table 1. Annual and average grain yields and other data of 19 rice varieties, Rice-Pasture Experiment Station, 1948-53

Variety	Grain type	Average[1]				Years grown	Grain yield, pounds per acre							Comparable yield[2]
		Date sown	Date ripe	No. days from seeding to maturity	Plant height, inches		1948	1949	1950	1951	1952	1953	Av.	
				Early-maturing varieties										
Caloro	Short	May 2	Sept. 12	133	45	6	1937	1193	3200	3722	4481	4342	3146	100.6
Calrose	Medium	May 5	Sept. 10	123	46	5		1686	2790	3797	4393	4049	3343	102.5
Zenith	Medium	May 2	Aug. 31	121	49	6	2752	2560	2774	3335	3699	3624	3124	99.9
Magnolia	Medium	May 2	Sept. 1	122	49	6	2625	2043	3197	3467	3440	3803	3096	99.0
Early Prolific	Medium	May 2	Sept. 4	125	52	6	2737	1882	3262	3193	4021	3724	3137	100.4
Lacross	Medium	May 7	Sept. 9	125	47	5	2825	2032	2957	2426	2611		2570	85.8
Century Patna	Long[3]	May 2	Sept. 2	123	46	6	2774	2643	3610	3933	3902	3302	3361	107.5
Average													3111	
				Midseason-maturing varieties										
Blue Rose	Medium	May 2	Sept. 28	159	52	6	2163	1819	3264	3257	4273	3422	3033	97.0
Bluebonnet	Long	May 2	Sept. 15	136	54	6	2451	2441	3825	3529	3986	3203	3239	103.6
Bluebonnet 50	Long	May 2	Sept. 15	136	50	6	2447	2215	3575	3619	3425	3271	3092	98.9
Improved Bluebonnet	Long	May 2	Sept. 20	141	52	6	2793	2320	3866	3671	3976	3392	3336	106.7
RN	Long	May 9	Sept. 23	137	51	4	2883	2474	3447	3644			3112	113.3
Fortuna	Long	May 2	Sept. 17	138	55	6	2434	2371	3573	3566	4117	3634	3283	105.0
Nira	Long	May 9	Sept. 20	134	62	4	2608	2277	3183	3179			2812	102.4
Rexark	Long[3]	May 2	Sept. 14	135	50	6	2522	1997	3479	3516	4221	2327	3010	96.3
Average													3115	
				Late-maturing varieties										
R-D[4]	Long[3]	May 2	Oct. 4	155	54	6	2724	2208	3715	3504	4698	3959	3468	110.9
Texas Patna	Long[3]	May 2	Oct. 8	159	58	6	1769	1715	3335	3172	4118	3240	2892	92.5
TP 49	Long[3]	May 2	Oct. 15	166	53	6	2369	2109	3152	2650	3821	3952	3009	96.3
Rexoro	Long[3]	May 2	Oct. 22	173	55	6	2318	1450	2663	2489	3548	3493	2660	85.1
Average													3070	

[1]Date sown represents the average date sown with earliest date April 8 and latest date May 27. Plant height represents the average height for the years grown, except late varieties which are for the period 1949-53.
[2]Percent of the average yield of all varieties, except Calrose, RN, Lacross and Nira, for the years grown.
[3]Long-slender grain.
[4]Scented variety.

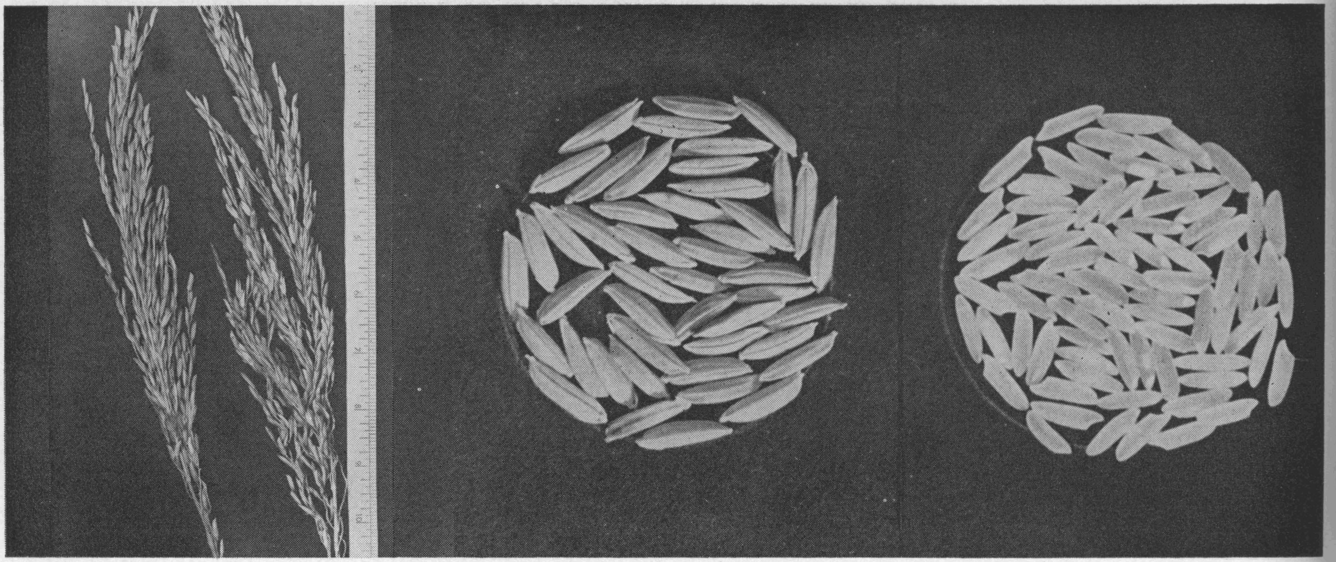

Figure 7. A typical head of Rexoro rice, and rough and milled rice.

growing conditions in the Texas rice belt. Some of these proved to be adapted. Others, though not suitable for commercial production, have been useful as breeding material in the development of new and better varieties.

Some of the results of the early work on testing varieties were given in Texas Station Bulletin 200, which was published in 1916. A summary of most of the work from 1914 to 1932 was published in 1933 in Bulletin 485.

The rice improvement program, including the breeding, development and testing of new varieties, brought about varieties superior to the older ones in certain characteristics such as yield, milling quality, resistance to diseases, adaptation to combine harvesting, grain type and cooking quality. Consequently, these new varieties gradually replaced the older ones in commercial production in Texas.

Results of the variety tests conducted in 1948-53 are given in Table 1. Varieties are listed according to maturity and type of grain. In the early-maturing group, Century Patna, a long, slender-grain variety, produced the highest average yield, 3,361 pounds per acre, or about 8 percent more than Zenith.

Of the eight varieties in the midseason group, RN, Improved Bluebonnet, Bluebonnet and Fortuna made higher yields. Fortuna and Nira also produced yields higher than the average for all varieties.

As a group, the late-maturing varieties did not yield as well as the early and midseason varieties. R-D, a scented variety, however, made next to the highest comparable yield in the test, or about 11 percent more than the average yield of all varieties.

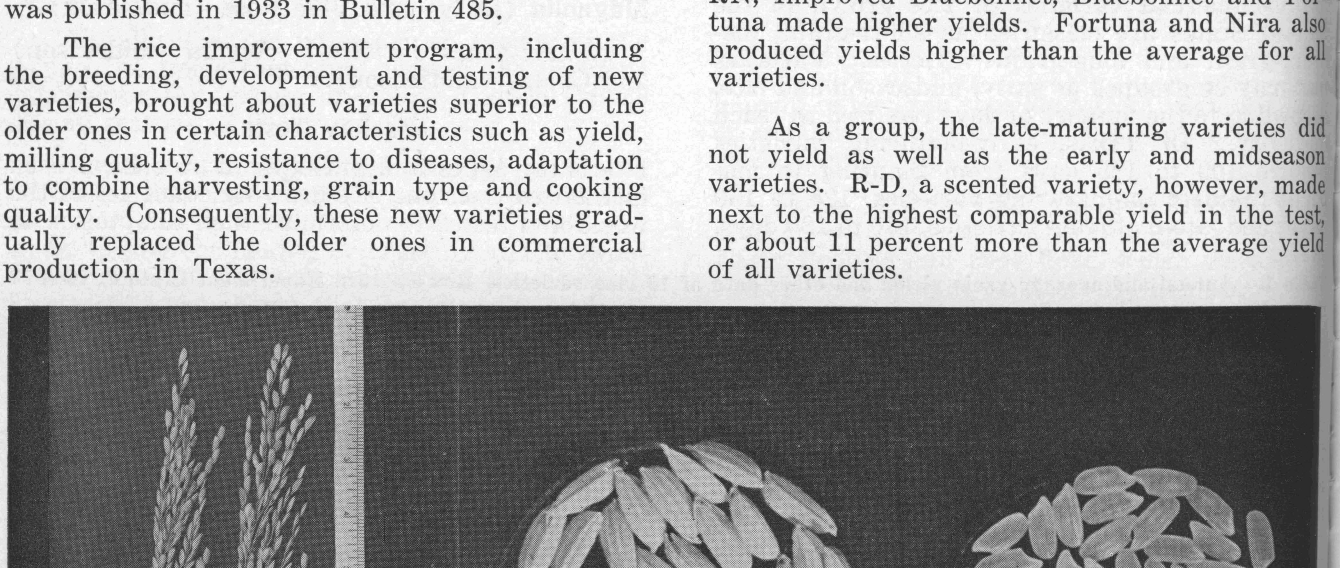

Figure 8. A typical head of Zenith rice, and rough and milled rice.

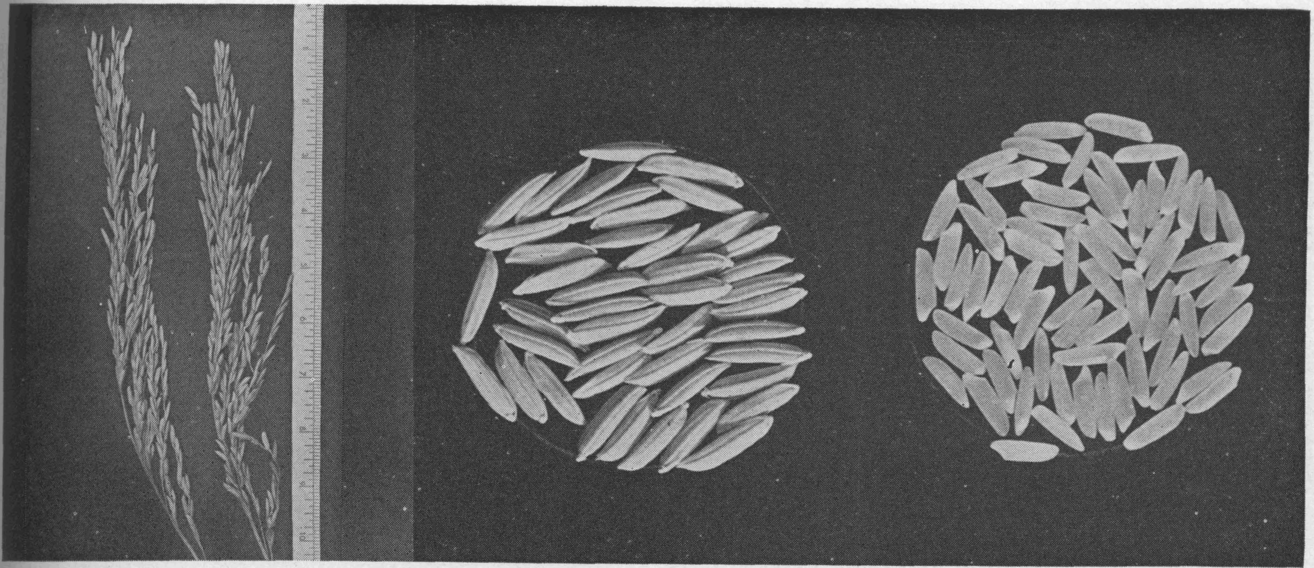

Figure 9. A head of Century Patna rice, and rough and milled rice.

Varieties Recommended for Texas

Short descriptions follow of the rice varieties recommended for Texas.

Although yield is one of the most important characteristics in selecting a variety to plant, other factors to be considered are date of maturity, type of grain, stiffness of straw and milling and table qualities. If the rice grower has a large acreage, he probably should grow two or three varieties that differ in date of maturity and type of grain. This extends the harvest over a longer period and gives better distribution of labor and more efficient use of harvesting machinery. Rice harvested early may be sold to help finance the harvesting of the later varieties. Rice of different grain types will be available for sale, thus enabling the grower to take advantage of premium prices for long, medium or short types, should they occur.

Bluebonnet

Bluebonnet, a midseason, long-grain variety, was developed at the Rice-Pasture Experiment Station from a selection from a cross of Rexoro and Fortuna. It is resistant to some of the common rice diseases but is susceptible to others. It yields and mills well and has good table quality. Bluebonnet is well suited for harvesting by the combine-dryer method.

Bluebonnet 50

Bluebonnet 50, a selection from Bluebonnet, was released by the Rice-Pasture Experiment Station in 1951. It is more uniform than Bluebonnet in maturity and grain size. Because of its shorter, sturdier straw, Bluebonnet 50 is gradually replacing Bluebonnet and, along with Century Patna, is one of the leading long-grain varieties grown in Texas.

Improved Bluebonnet

Improved Bluebonnet was developed at the Rice-Pasture Experiment Station and released in 1951. It is a selection from a cross of Rexoro and Nira and has a grain type similar to that of Bluebonnet, but the grain is more slender. It has a more vigorous vegetative growth than Bluebonnet, and its leaves and stems do not dry out as rapidly as the plants approach maturity. It matures 4 to 6 days later than Bluebonnet. Improved Bluebonnet is resistant to most rice diseases, but is susceptible to stem rot. Because of its rather vigorous vegetative growth, Improved Bluebonnet is well adapted to land that has been heavily cropped.

Rexoro

Rexoro is a stiff-strawed, late-maturing, long slender-grain rice developed at the Rice Experiment Station, Crowley, Louisiana (23). It yields and mills well and has good table quality. Rexoro is resistant to white tip but is susceptible to stem rot, cercospera leaf spot and straighthead disease. Because of its late maturity and susceptibility to straighthead, rather low yields are frequently obtained.

Zenith

Zenith is an early-maturing, awnless variety developed at the Rice Branch Experiment Station, Stuttgart, Arkansas (23). It is susceptible to the brown leaf spot disease but is somewhat resistant to some strains of the narrow brown leaf spot disease and to stem rot. Zenith is the leading medium-grain variety grown in the United States, but is not widely grown in Texas. Milling quality is satisfactory but is not equal to that of Magnolia or Blue Rose.

Magnolia

Magnolia, an early-maturing, medium-grain variety, was developed at the Rice Experiment

Station, Crowley, Louisiana, from a selection from a cross of Fortuna and Blue Rose (23). It is moderately resistant to some races of the narrow brown leaf spot disease and to stem rot, but is susceptible to other common diseases. It has stiff straw, does not lodge readily and, under favorable conditions, produces relatively high yields of good milling quality.

Century Patna 231

Century Patna was selected in 1946 at the Rice-Pasture Experiment Station from a cross between Texas Patna and a selection from the cross Rexoro x Supreme Blue Rose. It was released to farmers in the spring of 1951. It is a high-yielding, early-maturing variety with long, slender grains. Century Patna 231 is moderately resistant to the common races of the narrow brown leaf spot disease, and the leaves and stems remain alive for some time after maturity. It is rather susceptible to straighthead disease. Its cooking quality is about the same as that of Rexoro and Texas Patna, but it may require longer to cook and is not as good as Rexoro or Texas Patna for use in the parboiled rice process.

Texas Patna

Texas Patna, a late-maturing, long, slender-grain variety, was selected in 1935 from a cross between Rexoro and C.I. No. 5094 at the Rice-Pasture Experiment Station. It is resistant to the white tip disease, but is susceptible to most of the leaf spot diseases. Texas Patna is similar to Rexoro but usually has slightly taller and weaker straw, and matures about 10 days earlier. It yields and mills well, and is well suited for combining and the grain is easy to dry. Texas Patna has excellent cooking quality.

TP 49

TP 49 was selected from a cross between Texas Patna and a Rexoro x C.I. 7689 selection in 1945 at the Rice-Pasture Experiment Station. The C.I. 7689 parent was a Patna variety introduced from India. TP 49 possesses exceptional vegetative vigor and is adapted to heavily cropped lands or lands heavily infested with weeds. It matures at about the same time as Texas Patna. TP 49 has slightly longer and fuller grains than Rexoro and about the same cooking quality as Rexoro and Texas Patna.

Milling Quality of Varieties

Yields of whole grain rice and total rice after removal of the hulls and bran determine to a large extent the milling quality of rice. Weather conditions during ripening and harvest, methods of drying and storing, variety, insects and diseases may affect milling quality.

Average yields of head rice and total rice of nine varieties grown in a date-of-seeding experiment at Beaumont in 1951-53 are given in Table 2.

Magnolia gave higher average head and total rice yields than Zenith, and both of these medium-grain varieties gave higher yields of head rice than the long-grain varieties.

Century Patna gave the highest head rice yield of the long-grain varieties, and TP 49 the lowest.

Century Patna and Improved Bluebonnet made the lowest total rice yields. Rexoro produced a relatively low average total yield, although the April and May seedings had high total rice yields. The low yield of rice produced in the June seeding was probably due to low temperatures occurring in late October and early November, which prevented normal development of the grain. Rexoro produces high total rice yields when sown at optimum dates of seeding.

In most instances, Zenith, Century Patna, Bluebonnet and Bluebonnet 50 produced higher average total rice yields when sown in June or July than when sown earlier. A possible explanation for this is that the cooler weather prevailing during September and early October is more favorable for the development of the rice grain than the higher temperatures of late July and early August. Although slightly lower temperatures appear to improve milling quality, the lower temperatures of late October and early November seriously affect normal grain development and milling quality, as indicated by milling yields of

Table 2. Average yields of milled rice of nine varieties seeded at different dates, Rice-Pasture Experiment Station, 1951-53

Variety	March 17		April 15		May 17		June 13		July 10		Average	
	Head rice	Total rice	Head rice	Total rice	Head rice	Total rice	Head rice	Total rice	Head rice	Total rice	Head rice	Total rice
	Percent											
Early-maturing varieties												
Magnolia	66.9	70.9	68.4	72.1	67.6	72.1	67.1	72.4	70.6	72.7	68.1	72.0
Zenith	66.1	70.5	63.9	69.3	63.8	68.5	58.7	70.0	70.3	72.1	64.6	70.1
Century Patna 231	60.8	67.0	60.7	66.5	59.8	67.4	62.9	68.8	64.0	70.2	61.6	68.0
Average	64.6	69.5	64.3	69.3	63.7	69.3	62.9	70.4	68.3	71.7		
Midseason-maturing varieties												
Bluebonnet	50.8	70.8	43.8	70.8	49.5	71.5	55.2	71.8	50.4	72.8	49.9	71.5
Bluebonnet 50	51.2	69.7	41.2	69.0	52.2	71.0	54.8	71.9	51.7	72.0	50.2	70.7
Improved Bluebonnet	52.2	68.4	52.8	68.3	58.6	69.1	52.6	70.6	28.3	64.2	49.9	68.1
Average	51.4	69.6	45.9	69.4	53.4	70.5	54.2	71.4	43.5	69.7		
Late-maturing varieties												
Texas Patna	53.4	67.2	53.9	69.2	60.8	70.8	58.8	72.4	[1]	[1]	56.7	69.9
TP 49	47.2	68.8	40.7	70.2	53.3	71.2	53.0	73.0	[1]	[1]	48.6	70.8
Rexoro	55.4	69.3	58.4	71.4	62.6	73.1	33.4	64.4	[1]	[1]	52.5	69.6
Average	52.0	68.4	51.0	70.3	58.9	71.7	48.4	69.9				
Average all varieties	56.0	69.2	53.8	69.6	58.7	70.5	55.2	70.6	55.9	70.7		

[1] Failed to mature all years.

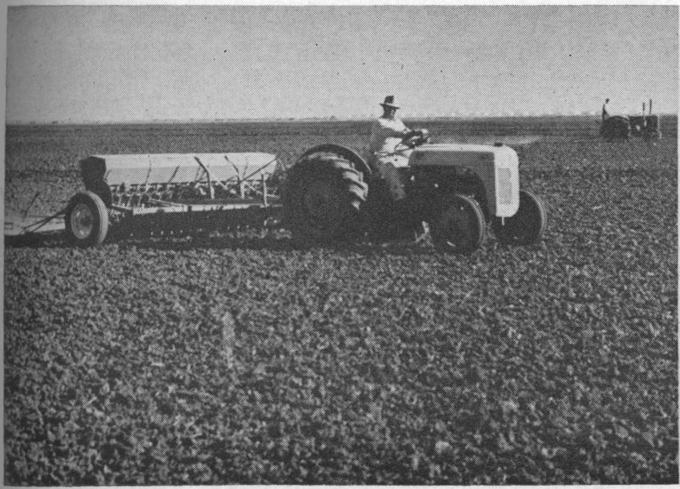
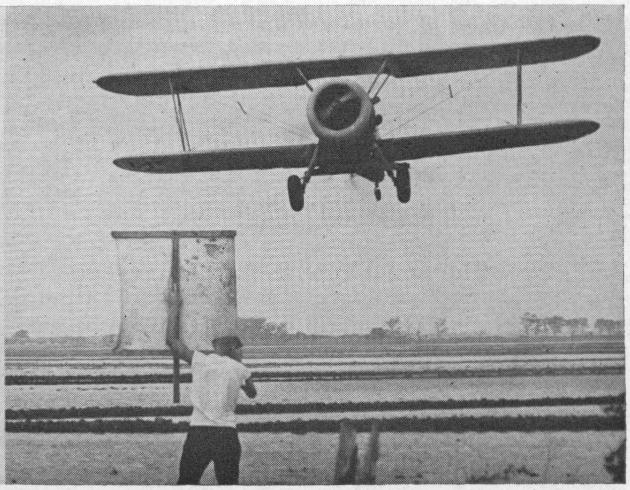

Figure 10. Seeding rice with a grain drill (left) and with an airplane (right).

all the late-maturing varieties sown in June, and of Improved Bluebonnet sown in July.

Bluebonnet, Bluebonnet 50 and Improved Bluebonnet produced low average head rice yields when sown in April. The ripening period of these varieties when sown in April corresponds with the period of highest summer temperatures. Bluebonnet and Bluebonnet 50 probably are more sensitive to unfavorable weather conditions during ripening and harvest than other varieties. In 1951, when extremely high temperatures and low humidity prevailed during August, the April seeding of Bluebonnet yielded only 25.4 percent of head rice.

SEEDING

Methods of Seeding

Grain Drill and Endgate Seeders

Rice usually is seeded in Texas with a grain drill, Figure 10, but seeding by airplane is increasing rapidly. Broadcast seeders are used to some extent. On rough, dry seedbeds, rice frequently is broadcast with endgate seeders or with a drill with disks removed. In either case, the land is then harrowed and irrigated.

Airplane

Seeding by airplane is used extensively in Texas and the practice is increasing each year, especially for early seedings (46). It is estimated that 105,000 acres were seeded from airplanes in 1952 and 110,000 acres in 1953. Airplane seeding may be done in water or on dry soil. Water seeding requires different seedbed preparation than seeding with a grain drill. For water seeding, the land is plowed and disked to kill vegetation. It is left in a rough condition until seeding time. Then the field is irrigated to barely cover the land. The field is then harrowed to muddy the water. Pre-soaked seed are then sown by airplane on the water, Figure 11. Dry seed are used for airplane seeding on dry soil.

When seeding is done on dry soil, fields usually are harrowed following seeding and then flushed and resubmerged in time to control the growth of weeds and grass. For water-seeded rice, some farmers drain as soon as possible while others may delay draining as much at 36 hours. In some instances, the water is not drained from the fields after water seeding. In such cases, a shallow flood is held until the rice plants have become established. This method should be practiced cautiously and only when uniform flooding of the land is possible.

Comparison of Drilled and Broadcast Seeding

An experiment was conducted at Beaumont in 1952 to compare drilled and broadcast seeding of rice. The work was done in conjunction with rates of seeding and fertilizer treatments in which rice was drilled and broadcast at rates of 45, 90, 135 and 180 pounds per acre.

A summary of the results is presented in Table 3. Yields of the different rates of seeding are the averages of yields from five different fertilizer treatments. Broadcast seeding produced somewhat larger yields of rough rice than

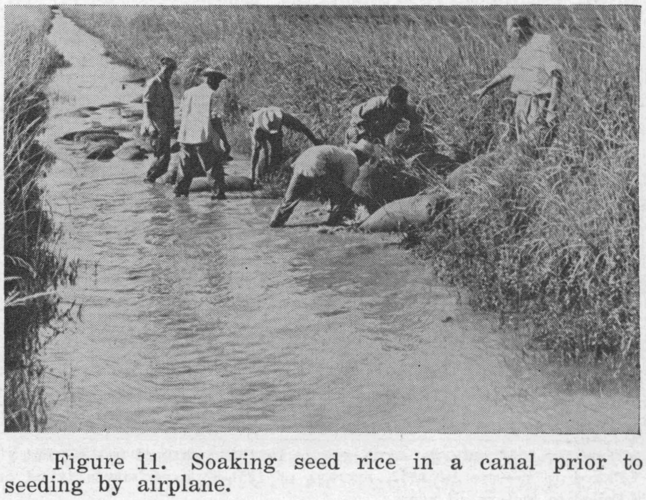

Figure 11. Soaking seed rice in a canal prior to seeding by airplane.

Table 3. Yields of rough rice from drilled and broadcast seedings at different rates, Rice-Pasture Experiment Station, 1952

Rate of seeding pounds per acre	Yield in pounds of rough rice per acre		
	Drilled	Broadcast	Average
45	4,735	5,007	4,871
90	4,609	5,032	4,820
135	4,479	4,693	4,586
180	4,251	4,753	4,502
Average	4,518	4,871	

drilled seeding at all rates. As an average of the four rates, drilled seeding produced 4,518 pounds of rough rice per acre and broadcast seeding, 4,871 pounds.

Time of Seeding

The time of seeding rice in Texas ranges from March 1 to late June. Probably most of the rice acreage is seeded in April and May. The actual time of seeding, however, may depend on several factors, such as the weather, method of seeding, soil condition and the maturity of the variety. When seeded late in the spring when temperatures are high, rice germinates more rapidly than when seeded earlier. Seed sown early are more apt to rot because of low temperatures. When sown early in the spring, the medium-grain varieties Zenith and Magnolia usually produce better stands than long-grain varieties, since they seem to be more tolerant to low temperatures during germination and early seedling growth. It may be advisable for the rice grower to spread the planting of certain varieties so that the harvest can be extended over a longer period.

Experiments to determine the best dates of seeding rice were conducted at Beaumont from 1914 through 1918. Seedings were made at 2-week intervals from March 15 to late June. There was not much difference in yield from seedings made between April 15 to June 1 (28). Lower yields were obtained from plantings made earlier or later than this period.

Date of seeding greatly affects the time required for rice to mature, as shown by experiments conducted at Beaumont in 1951-53, Table 4. Nine varieties were seeded March 17, April 15, May 17, June 13 and July 10. For all varieties, the time required to maturity decreased as the seeding was delayed until May 17. When seeded June 13, Rexoro, Texas Patna and TP 49 were damaged by frost or did not mature. They did not mature when seeded July 10. These results indicate that all varieties do not respond alike to time of seeding.

Yields of rough rice obtained in the experiment on time of seeding also are presented in Table 4. Yields of early-maturing varieties were about the same whether seeded in March or June. The average yield of the midseason varieties decreased markedly as seeding was delayed. Bluebonnet 50, however, made almost identical yields when seeded March 17 and April 15. The average yield of the late-maturing varieties also decreased sharply as seeding was delayed. From these results, it appears that the late-maturing varieties should be seeded as early as practicable to insure satisfactory yields.

Rate of Seeding

Rate of seeding rice may vary considerably, depending on soil condition, quality of seed and time and method of seeding. In farm practice in Texas, the rate of seeding ranges from 60 to 125 pounds per acre. The average is about 90 pounds. In experiments on rates of seeding conducted at Beaumont from 1914 to 1918, seeding 100 pounds of seed per acre produced slightly larger yields of rough rice than seedings of 60 and 80 pounds (28).

The rate of seeding also varies greatly in different parts of the rice belt of Texas. In the more humid areas, such as Chambers, Jefferson, Liberty and Orange counties, higher rates of seeding are used. In the western counties of the area, Colorado, Jackson, Wharton, parts of Harris and other counties, rates of seeding as low as 60 pounds per acre are frequently used. Lower rates of seeding than those commonly used probably can be practiced successfully in Texas.

A rather comprehensive experiment, which included four rates of seeding and six fertilizer

Table 4. Average yields and number of days from seeding to maturity of nine rice varieties seeded at different dates, Rice-Pasture Experiment Station, 1951-53

Variety	Average number of days from seeding to maturity when sown					Average acre yield in pounds when sown				
	March 17	April 15	May 17	June 13	July 10[1]	March 17	April 15	May 17	June 13	July 10[1]
Early-maturing varieties										
Magnolia	140	123	113	117	121	2662	3223	2668	3003	2799
Zenith	140	122	113	116	121	3042	3466	2901	3223	2729
Century Patna 231	144	126	117	121	123	3426	3312	3410	3601	2628
Average	141	124	115	118	122	3043	3334	2993	3276	2719
Midseason-maturing varieties										
Bluebonnet	156	138	132	130	151	3892	3613	2971	2773	1788
Bluebonnet 50	156	137	132	130	151	3783	3816	3170	3277	1971
Improved Bluebonnet	162	141	137	137	151	3953	3612	3438	3037	926
Average	158	139	134	132	151	3876	3680	3192	3029	1562
Late-maturing varieties										
Texas Patna	182	168	159	154[2]	[3]	3427	2772	2463	1259[2]	[3]
TP 49	186	173	162	154[2]	[3]	3343	2768	2722	1561[2]	[3]
Rexoro	196	180	172	159[2]	[3]	3200	2849	2350	1040[2]	[3]
Average	188	174	164	156	[3]	3323	2796	2512	1253	[3]

[1] Yield for 1953 only, failed to mature in 1952, matured in 1951 but yield not recorded.
[2] Failed to mature in 1952, average of 1951-52 experiments (yield on 3-year basis but only 2 crops produced).
[3] Failed to mature all years.

treatments, was conducted at Beaumont in 1950-52, to determine the optimum rate of seeding rice under several levels of fertility. Seed of Bluebonnet 50 were broadcast at rates of 45, 90, 135 and 180 pounds per acre. Fertilizers were applied on the surface with a fertilizer-grain drill at the time of seeding.

The fertilizer treatments in the first column of Table 5 show the pounds of nitrogen (N), phosphoric acid (P_2O_5) and potash (K_2O), in the order named, which were used per acre. Thus, the 160-80-80 fertilizer means that 160 pounds of nitrogen, 80 pounds of phosphoric acid and 80 pounds of potash were applied per acre. There were no significant differences in the average yields of rough rice from the seeding rates of 90, 135 and 180 pounds per acre. Yields from these rates of seeding, however, were significantly higher than from the seeding of 45 pounds per acre. These results indicate that the optimum rate of seeding probably would be about 90 pounds per acre. They are in agreement with results of the 1914-18 experiments. Where weeds and grass are troublesome, the heavier rates of seeding probably will give the best results.

Depth of Seeding

Where rice is seeded with the grain drill, the seed should be placed 1 to 2 inches deep. In experiments on depths of seeding conducted at Beaumont from 1914 to 1918, placing the seed 2 inches deep produced slightly higher yields of rice than placing the seed 1 or 3 inches deep (28). As with most other field crops, there usually is less danger of rotting from shallow seeding than from deep seeding, especially if it is necessary to irrigate to germinate the seed. Seed may be planted deeper on sandy soils, such as Katy and Hockley soils, than on heavy soils, such as Beaumont clay and Lake Charles clay.

Rice seeded deep early in the season is more apt to rot during periods of unfavorably cool weather than when seeded shallow. This is particularly true in the heavier soil types. For this reason, broadcast seeding followed by harrowing is frequently practiced on early-seeded rice on clay soils.

Table 5. **Average yields of rough rice from different rates of broadcast seeding and different fertilizer treatments, Rice-Pasture Experiment Station, 1950-52**

$N-P_2O_5-K_2O$, pounds per acre	Yield in pounds per acre of rough rice from seeding rates of[1] 45 lbs.	90 lbs.	135 lbs.	180 lbs.	Average[2]
0-0-0	3,492	3,843	3,780	3,836	3,738
40-20-0	4,015	4,305	4,576	4,641	4,384
80-40-0	4,723	4,661	4,701	4,995	4,770
120-60-0	4,878	4,752	4,972	4,587	4,797
160-80-0	4,873	5,219	4,984	5,200	5,069
160-80-80	4,702	5,294	5,065	5,135	5,049
Average[3]	4,447	4,679	4,680	4,732	

[1] The difference between the yields of rice from any two fertilizer treatments among the four rates of seeding (9 plots) must equal or exceed 387 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

[2] The difference between the average yields of any two fertilizer treatments (average of 36 plots) must equal or exceed 194 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

[3] The difference between the average yields of any two rates of seeding (54 plots) must equal or exceed 159 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

FERTILIZERS

Soils in the rice-growing area of Texas are somewhat variable in texture, structure, drainage and productiveness. Yields of rice also vary considerably on these soils, depending on the kind of soil and on previous management, such as cropping and fertilization. The Rice-Pasture Experiment Station has conducted experiments with fertilizers since 1919 to determine the best fertilizer practice for rice in the area. In the earlier work, it was found that some rice soils, especially Lake Charles clay, Lake Charles clay loam and Beaumont clay (previously called Crowley clay) responded to applications of nitrogen and phosphorus, but not to potash (34). Application of fertilizers as a top-dressing 6 to 12 weeks after seeding produced somewhat larger yields of rice than applications at seeding time.

Work conducted from 1930 to 1940 confirmed the earlier results (48). It also showed that broadcast applications of superphosphate alone at planting caused a reduction in yield. This was attributed to the increase in growth of grasses and weeds which competed with the rice for plant nutrients. Drilling fertilizer, especially sulfate of ammonia, with the seed was slightly better than broadcasting the fertilizer on top of the soil at seeding. There was little difference in the yields of rice from different sources of nitrogen and phosphorus.

More comprehensive work with fertilizers was started in 1947. It was conducted on the Beaumont station and on farms of rice growers throughout the rice belt, Figure 1. This work included different sources, rates and ratios of nitrogen, phosphorus and potash; time and methods of application; and application of fertilizers on dry, wet and flooded soils.

Methods of Applying Fertilizers

Several methods of applying fertilizers for rice are used in the Texas rice belt.

Fertilizer-Grain Drill

Ground application with the fertilizer-grain drill is probably the most common method in applying fertilizers for rice. Where the fertilizer drill is used, the fertilizer may be broadcast on the surface or applied in the drill with the seed as desired. Previous work at the Beaumont station (48) indicated that fertilizers applied in the drill with the seed produced somewhat larger yields of rice than fertilizers applied on the surface at seeding. However, applications of fertilizer at time of seeding on grass-infested soil may cause a severe reduction in yield.

Airplane

Application of fertilizers by airplane is increasing rapidly in Texas and probably will continue to increase. Sulfate of ammonia may be applied with good results by airplane to fields prior to flooding of the rice up to 35 or 40 days after seeding.

Application in Water

Some fertilizers may be applied in the irrigation water as it is being turned into the field. At present, anhydrous ammonia is the principal material used in this way. Although application in water may give fair increases in yield of rice, experiments at Beaumont show that application by injection into the soil gives considerably higher yields. It is difficult in many cases to obtain uniform distribution of ammonia by application in water. Application of anhydrous ammonia in irrigation water is said to be impractical in California because of the uneven distribution of nitrogen over the field (16).

Placement of Fertilizer

Experiments on placement of fertilizer with respect to the seed were conducted at Beaumont in 1950-52. The several placements and fertilizers used are given in Table 6. Placing the fertilizer in the drill row 2 inches below the seed and delayed broadcast application produced the highest average yields, 4,011, 4,097 and 4,001 pounds per acre, respectively, for the 3 years. There were, however, no significant differences among the yields from any of the placements. Applying the fertilizer at time of seeding on grass-infested fields may cause a reduction in yield, Table 14.

Table 6. Yield of rough rice from different placement of fertilizer, Rice-Pasture Experiment Station, 1950-52

Placement of fertilizer	Yields in pounds of rough rice per acre from fertilizer treatments			
	60-30-0	80-40-0	100-50-0	Average
With seed	3,685	4,086	4,261	4,011
2 inches below seed	3,898	4,087	4,306	4,097
3.5 inches to side of seed	3,818	3,904	3,903	3,875
2 inches below and 3.5 inches to side of seed	3,489	3,930	3,901	3,773
Broadcast on surface at planting	3,339	3,933	3,946	3,739
Delayed broadcast application	3,548	4,052	4,402	4,001
Average	3,629	3,999	4,120	

Rates and Ratios of Nitrogen, Phosphorus and Potash

Experiments with fertilizers have been conducted for the past several years on the principal soils used for growing rice in the Gulf Coast Prairie of Texas (10). The soils are Beaumont clay, Lake Charles clay, Lake Charles clay loam, Katy fine sandy loam, Hockley fine sandy loam and Edna fine sandy loam. It is estimated that these soil types comprise more than 80 percent of the rice land in Texas.

Nitrogen was used at rates of 0, 20, 40, 80 and 120 pounds per acre; phosphoric acid at 0, 20, 40 and 80 pounds per acre; and potash at 0 and 40 pounds per acre. These rates of nitrogen, phosphoric acid and potash were used in all possible combinations. Some typical results of these experiments are given in Table 7.

Figure 12. Fertilizers increase growth and yield of rice. Left to right: plot treated with 20 pounds of phosphoric acid and 100 pounds of potash per acre; 80 pounds of nitrogen and 60 pounds of phosphoric acid; 200 pounds of nitrogen and 100 pounds of phosphoric acid; and 20 pounds of nitrogen and 20 pounds of potash.

Table 7. Average yields of rice from applications of varying amounts of nitrogen, phosphoric acid and potash on different soils, 1947-50

Kind of fertilizer	Average yield of rice, pounds per acre					
	Beaumont clay	Lake Charles clay	Lake Charles clay loam	Katy fine sandy loam	Hockley fine sandy loam	Edna fine sandy loam
			Applied at the time of planting			
No fertilizer	2,108	3,084	2,448	2,678	3,313	3,099
40-0-0	2,514	3,397	2,696	2,824	3,361	3,502
80-0-0	3,076	3,912	2,879	2,908	3,480	3,985
0-40-0	2,023	3,353	2,381	2,929	3,298	3,076
40-40-0	2,391	3,600	2,417	3,230	3,473	3,958
80-40-0	2,752	4,193	2,965	3,068	3,391	4,481
40-40-40	2,467	3,930	2,610	3,122	3,460	3,948
80-40-40	2,793	4,193	2,816	3,300	3,755	4,599
Average[1]	2,574	3,797	2,681	3,054	3,460	3,936
			Applied as top-dressing			
40-0-0	2,658	3,882	2,764	2,944	3,663	3,297
80-0-0	3,036	3,990	2,887	3,195	3,771	3,595
0-40-0	2,027	3,083	2,496	3,159	3,311	3,381
40-40-0	2,835	3,590	2,955	3,517	3,930	3,856
80-40-0	3,285	3,966	3,279	3,412	3,950	4,141
40-40-40	2,655	3,731	2,960	3,624	3,779	3,833
80-40-40	3,378	3,776	3,198	3,509	3,792	4,210
Average[1]	2,839	3,717	2,934	3,337	3,742	3,759

[1] Does not include the yield from unfertilized soil.

Beaumont Clay

This soil is acid, poorly drained and very slowly permeable. It occurs mainly east of the Trinity River and probably comprises about one-fourth of the rice land in the State.

The combination of 80 pounds of nitrogen and 40 pounds of phosphoric acid (80-40-0) was one of the best treatments used as a top-dressing, as shown in Table 7. It produced an average yield of 3,285 pounds per acre, or 1,777 pounds more than unfertilized rice. When the fertilizer was applied at planting, the treatment of 80 pounds of nitrogen per acre made the highest yield, 3,076 pounds per acre. The use of 80-40-0 is recommended for Beaumont clay.

Lake Charles Clay

Lake Charles clay is the principal heavy soil in the rice belt west of the Trinity River. It comprises probably one-third to one-half of the rice acreage around Houston, Angleton, Bay City and El Campo. Lake Charles clay is darker in color and more granular than Beaumont clay. It is slightly acid to mildly alkaline in reaction, with a pH of 6 to 8.

The application of 80-40-0 at time of seeding made the highest yield on this soil, 4,193 pounds per acre, which was 1,109 pounds more than the yield of the untreated soil. This treatment also produced one of the highest yields where the fertilizers were applied as a top-dressing. The use of 80-40-0 is recommended for rice on Lake Charles clay.

Lake Charles Clay Loam

Lake Charles clay loam is similar to Lake Charles clay but is more loamy, slightly less dark, and occurs on slightly higher elevations. It is found both east and west of the Trinity River. This soil is slightly acid to neutral in reaction, with a pH of 6 to 7. An 80-40-0 fertilizer is recommended for rice on Lake Charles clay loam.

Katy Fine Sandy Loam

This soil occurs in large level areas adjacent to Lake Charles soils and in the flatter portion between the slightly more sloping and better drained Hockley soils. The town of Katy is located on Katy fine sandy loam from which the soil gets its name. A combination of 40 pounds each of nitrogen and phosphoric acid (40-40-0) was one of the best treatments on this soil. Potash used with both nitrogen and phosphoric acid, made increases in yield in approximately half of the experiments on this soil. For this reason, a 40-40-20 fertilizer is recommended on Katy fine sandy loam.

Hockley Fine Sandy Loam

The Hockley soils form a narrow belt along the northern part of the rice area from Cleveland in Liberty county, westward through Hockley, Sealy and Eagle Lake to western Victoria county. These sandy loam soils are underlain by friable sandy clay subsoils. They are slightly more sloping and better drained, and require more irrigation water than the Katy soils.

This soil responds to fertilizers about the same as Katy fine sandy loam. Treatments of 40-40-0 and 80-40-0 produced the highest yields. There was practically no difference in the yields of the two treatments. The 40-40-0 fertilizer is recommended on Hockley fine sandy loam.

Edna Fine Sandy Loam

This soil has a grayish sandy surface and is underlain at a depth of 6 to 12 inches by a heavy, gray claypan. It is found principally in the western and southwestern parts of the rice belt.

The treatment of 80-40-0 was the most profitable on Edna fine sandy loam. This treatment on clean land increased the yield 1,382 pounds per acre when applied at seeding and 1,042 pounds when applied as a top-dressing.

Possible Use of Potash on Sandy Soils

Although potash may not affect the yield of rice on some sandy soils, many rice growers believe that its use will result in a stiffer straw and a higher yield of head rice. Experimental data obtained so far, however, do not show any appreciable effect of potash on the milling quality of rice. The effect of potash on stiffness of straw in rice has not yet been determined. Potash has prevented lodging of other crops on some soils and also may serve the same purpose for rice. In areas where potash is used on other crops and where most of the fertilizer stocked by dealers contains potash, this fertilizer also may be used on rice.

Comparison of Nitrogenous Fertilizer Materials

Experiments have been conducted to evaluate different nitrogenous materials as fertilizers for rice. Work conducted from 1936 to 1940 (48) indicated that there was not much difference in the value of the nitrogenous materials tested.

Solid Nitrogenous Fertilizer Materials

Six solid nitrogenous materials—sulfate of ammonia, ammonium nitrate, nitrate of soda, cyanamid, urea and ureaform—were included in an experiment on Beaumont clay in 1949-50 (50). Each material was used at a rate to supply 80 pounds of nitrogen per acre. The materials were applied alone and in combination with 80 pounds per acre of phosphoric acid in 20 percent superphosphate, with 2 tons of lime, and with a combination of phosphoric acid and lime. The several treatments were applied when the rice was seeded and as a top-dressing about 60 days after seeding.

All of the nitrogenous materials produced significant increases in yields of rice on both dates of application, Table 8. Sulfate of ammonia, urea and cyanamid produced significantly larger yields than the other sources of nitrogen. There were, however, no significant differences among the average yields of rice which received these three sources of nitrogen.

The use of nitrogen and phosphoric acid together increased the yield of rice 544 pounds per acre above that produced by nitrogen alone. Lime had no appreciable influence on yield. As an average of all the nitrogenous materials, there was no real difference in the yield of rice whether they were applied at planting or as a top-dressing about 60 days after planting.

A similar experiment (50) with the same nitrogenous materials used at rates to supply 80 pounds of nitrogen per acre was conducted on Lake Charles clay near Bay City in 1950, Table 9. All of the fertilizer was applied as a top-dressing about 60 days after seeding. Sulfate of ammonia, urea, cyanamid and ammonium nitrate produced significantly larger yields of rice than nitrate of soda and the unfertilized soil.

Table 8. Comparison of the effect of different nitrogenous fertilizers on the yield of rice on Beaumont clay near Beaumont, as influenced by lime, phosphoric acid and time of application, 1949-50

Nitrogenous materials	Yield of rice, pounds per acre				
	No lime or phosphoric acid	Phosphoric acid	Lime	Lime and phosphoric acid	Average[1]
	Applied at planting				
No nitrogen	2,252	2,129	2,252	2,365	2,249
Ureaform	2,485	2,806	2,530	2,571	2,598
Nitrate of soda	2,231	3,020	2,352	2,833	2,609
Ammonium nitrate	2,543	2,984	2,339	2,887	2,688
Urea	2,759	3,339	2,710	3,256	3,016
Sulfate of ammonia	2,806	3,426	2,851	3,302	3,096
Cyanamid	2,958	3,347	2,984	3,499	3,197
Average	2,576	3,007	2,574	2,959	2,780
	Applied as a top-dressing				
No nitrogen	2,087	2,155	2,334	2,417	2,248
Nitrate of soda	2,526	2,809	2,381	3,221	2,734
Ureaform	2,676	3,153	2,655	2,948	2,858
Ammonium nitrate	2,553	3,094	2,521	3,280	2,862
Cyanamid	2,783	3,519	2,854	3,545	3,175
Urea	2,999	3,587	2,723	3,639	3,237
Sulfate of ammonia	3,068	3,830	2,699	3,600	3,299
Average	2,670	3,164	2,595	3,236	2,916

[1] The difference between any two averages shown must equal or exceed 186 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

Table 9. Yields of rice from different nitrogenous fertilizers with varying rates of phosphoric acid on Lake Charles clay soil near Bay City, 1950

Nitrogenous materials	Yield of rice, pounds per acre				
	Phosphoric acid, pounds per acre			Average[1]	Increase over no nitrogen
	0	40	80		
No nitrogen	3,583			3,583	
Nitrate of soda	3,813	3,998	4,191	4,001	418
Ureaform	4,018	4,099	4,267	4,128	545
Ammonium nitrate	4,120	4,474	4,722	4,439	856
Cyanamid	4,335	4,542	4,649	4,509	926
Urea	4,265	4,607	4,850	4,574	991
Sulfate of ammonia	4,342	4,782	4,808	4,644	1,061

[1] The difference between any two averages shown must equal or exceed 279 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

Anhydrous Ammonia

Anhydrous ammonia is a widely-used nitrogenous fertilizer. Experiments were conducted at Beaumont to compare anhydrous ammonia and sulfate of ammonia as fertilizers for rice and to develop satisfactory methods of applying anhydrous ammonia (52). Each material was used at a rate to supply 80 pounds of nitrogen per acre. Both were used in combination with 40 pounds per acre of phosphoric acid. In one experiment, anhydrous ammonia and sulfate of ammonia were applied on drill-seeded rice on dry soil, Table 10. In another experiment, the materials were used on rice that was broadcast on a flooded field, Table 11. The several methods of application are given in the tables.

Results of these two experiments indicate that anhydrous ammonia is equal to sulfate of ammonia, pound for pound of nitrogen, if these materials are applied just prior to seeding. Anhydrous ammonia gave good results when applied in the soil during the muddying-up operation for water-seeded rice, Table 10. Anhydrous ammonia can be used to advantage by injecting it in the soil with the growing crop, if soil conditions are favorable for using the equipment. This method of application should be followed as soon as possible with irrigation to prevent damage to stands.

Injection of the ammonia into the soil just prior to seeding produced larger yields of rice

Table 10. Yield of rice obtained from sulfate of ammonia and anhydrous ammonia applied by different methods to drill-planted rice in dry soil, Rice-Pasture Experiment Station, 1951[1]

Method and time of applying fertilizer	Yield of rice, pounds per acre[2]	
	Sulfate of ammonia	Anhydrous ammonia
Applied in the soil just prior to planting	4,580	4,789
Sulfate of ammonia on top of soil just before flushing. Anhydrous ammonia in the flushing water as it entered the field	4,215	3,862
Applied on shallow-flooded field 4 weeks after planting	3,805	3,494
Applied on field with full flood 4 weeks after planting	3,985	3,570
Applied on shallow-flooded field 8 weeks after planting	3,907	3,352
Applied on field with full flood 8 weeks after planting	3,812	3,368
Top-dressed on dry soil before flooding at 4 weeks	4,478	
Top-dressed on dry soil before flooding at 8 weeks	3,784	
Average	4,071	3,739

[1] Yield without nitrogen was 2,618 pounds per acre.
[2] The difference in yield between the two treatments shown must equal or exceed 334 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

Table 11. Yields of rice from sulfate of ammonia and anhydrous ammonia applied to water-planted rice, using soaked seed, Rice-Pasture Experiment Station, 1950[1]

Method and time of applying fertilizer	Yield of rice, pounds per acre[2]	
	Sulfate of ammonia	Anhydrous ammonia
Applied in soil prior to flooding for water planting	3,690	4,186
Applied in flooding water prior to muddying-up for planting	3,899	2,892
Applied in the soil during muddying-up operation		4,235
Injected into the soil on growing crop 4 weeks after planting		4,335

[1] Yield without nitrogen was 2,851 pounds per acre.
[2] The difference in yield between the two treatments shown must equal or exceed 512 pounds to give odds of 19 to 1 that such difference is real and not due to chance.

than injections about a month before seeding, Figure 13.

Applying anhydrous ammonia in the irrigation water as the field was flooded produced some increase in the yield of rice, but this method was not as effective as injecting the material into the soil, Table 11. Results of these experiments and observations on commercial rice fields indicate that certain precautions are necessary to obtain uniform distribution of the anhydrous ammonia over the field in the irrigation water. If the ammonia is to be applied in the irrigation water, the soil should be fairly dry at the time of flooding to permit the water to penetrate into the soil as rapidly as possible. The irrigation water should be distributed over the field in the shortest possible time and, if necessary, should be applied at several points where large fields are being irrigated.

These results obtained with nitrogenous fertilizers indicate that, pound for pound of nitrogen, ammonium nitrogen was somewhat superior to nitrate nitrogen. This conclusion is in general agreement with previous work at Beaumont (48), with results in Arkansas (6, 24) and with the review of world literature on the efficiency of various nitrogenous fertilizers for rice (4).

Effect of Moisture of Surface Soil

Experiments were conducted on Beaumont clay at the Rice-Pasture Experiment Station, 1946-50, to determine the effect of applying fertilizers as a top-dressing on dry, wet and flooded soils as indicated by the yield of rice. In one experiment (49), sulfate of ammonia and cynamid were applied at rates to supply 60 pounds of nitrogen per acre. In another test (51), sulfate of ammonia was applied in amounts to supply 60, 80 and 100 pounds of nitrogen per acre.

Table 12. Yields of rice in pounds per acre from applications of 60 pounds of nitrogen per acre in cyanamid and sulfate of ammonia on dry, wet and flooded soil, Rice-Pasture Experiment Station, 1946-48

Soil condition	Cyanamid	Sulfate of ammonia	Average
Dry	3,034	3,180	3,097
Wet	2,871	2,937	2,847
Flooded	2,211	2,247	2,345
Average	2,705	2,788	

Table 13. Effect of soil moisture conditions and different rates of nitrogen in sulfate of ammonia on yield of rice on Beaumont clay, Rice-Pasture Experiment Station, 1949-50

Soil condition	Yield of rice in pounds per acre from nitrogen at rates per acre of			
	60 lbs.	80 lbs.	100 lbs.	Average[1]
Dry	2,953	3,167	3,287	3,136
Wet	2,712	2,900	2,982	2,865
Flooded	2,493	2,662	2,775	2,643
Average	2,719	2,910	3,015	

[1] The difference in yield between any two averages must equal or exceed 147 pounds to give odds of 19 to 1 that the difference is real and not due to chance.

Results obtained from this comparison during 1946-48 are given in Table 12. Both materials produced somewhat larger yields on dry soil than on wet or flooded soil. Application of sulfate of ammonia to dry soil produced a higher average yield of rice during 1949-50 than application on wet or flooded soil (Table 13). The application of 60 pounds of nitrogen on dry soil produced a significantly higher yield of rice than applications of 80 and 100 pounds on flooded soil. Applications on wet soil also gave larger yields than applications on flooded soil.

Results of these two experiments show that the moisture condition of the soil surface influences the efficiency of nitrogenous fertilizers applied as top-dressings. Best results were obtained by applying cyanamid and sulfate of ammonia as top-dressing on dry soil.

Effect of Time of Fertilizer Application on Yields

Varieties of crops, including rice, may respond differently to environmental conditions, such as date of planting, spacing of plants, dates and rates of application of fertilizers and other factors.

An experiment was conducted at the Rice-Pasture Experiment Station in 1949-50 to deter-

Figure 13. Anhydrous ammonia was applied at a rate to supply 80 pounds of nitrogen per acre on both of these plots. The ammonia was injected into the soil just prior to seeding on the plot on the left and 6 weeks before seeding on the plot to the right. Note the difference in the growth of the rice on the two plots.

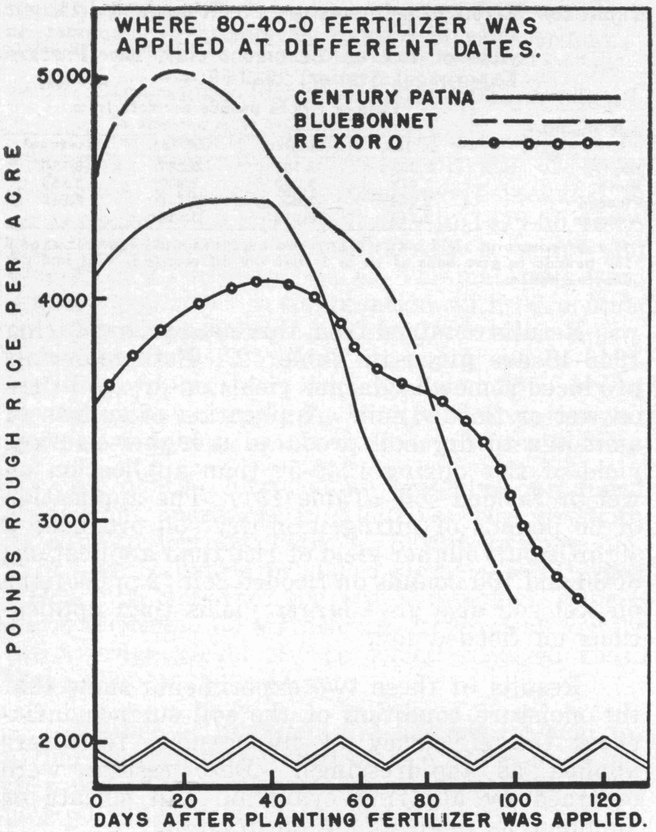

Figure 14. Showing the effect of time of application of fertilizer on yields of rice varieties of different maturity.

mine the response of early, midseason and late-maturing varieties of rice to applications of fertilizers at different dates (11). Three varieties were used: Century Patna, maturing in 115 to 125 days; Bluebonnet, maturing in 130 to 140 days; and Rexoro, maturing in 155 to 170 days. Single applications of 80-0-0 and 80-40-0 fertilizers were made at planting and as a top-dressing at dates ranging from 20 to 120 days after seeding.

Yields of rough rice are shown in Table 14 and are plotted in Figure 14. Applying the fertilizer at seeding and up to 40 days later produced the highest yield of Century Patna. Bluebonnet made the highest yield when the fertilizer was applied 20 days after seeding. Rexoro gave the best yield when the fertilizer was applied 20 to 40 days after seeding. An 80-40-0 fertilizer also was applied to the three varieties at different dates and in split applications. The results are given in Table 15.

The three varieties responded differently to time of application of fertilizer. Where early and midseason varieties are to be grown on land relatively free of grasses and weeds, all of the fertilizer could be applied at seeding or up to 40 days later with little difference in yield. If these varieties are grown on land where grasses and weeds are troublesome, all of the fertilizer should be applied as a top-dressing 35 to 40 days after seeding. Where late-maturing varieties are grown, all of the fertilizer should be applied as a top-dressing 35 to 40 days after seeding. With all varieties, applications of fertilizer 40 days after seeding were more effective than those made at a longer interval.

There were no significant differences in yields from single and split applications of fertilizer where the split applications were made at the proper time.

Table 14. Effect of time of application of nitrogen and of a combination of nitrogen and available phosphoric acid on the yield of Century Patna, Bluebonnet and Rexoro rice, Rice-Pasture Experiment Station, 1949-50

Time of application	Yield of rice, pounds per acre					
	Century Patna		Bluebonnet		Rexoro	
	80-0-0	80-40-0	80-0-0	80-40-0	80-0-0	80-40-0
At planting	3,337	4,099	3,434	4,552	2,997	3,515
20 days after planting	3,321	4,423	3,289	5,038	3,067	3,920
40 days after planting	3,856	4,439	3,969	4,649	3,386	4,099
60 days after planting	3,434	3,451	3,726	4,212	3,272	3,742
80 days after planting	2,948	2,932	3,418	3,613	3,353	3,580
100 days after planting			2,624	2,624	2,997	3,046
120 days after planting					2,527	2,543
Yield with no fertilizer	2,090		2,236		2,171	
Least significant difference[1]	356		292		308	

[1] The difference in yield between any two treatments at any date must equal or exceed the amount shown to give odds of 19 to 1 that such difference is real and not due to chance.

IRRIGATING RICE

Methods of irrigating rice vary in different countries of the world. Two general methods—continuous submergence and discontinuous submergence—are in common use in the United States. Both methods are used in Texas, although discontinuous submergence probably is used more extensively.

A review of the literature shows that little fundamental work has been done to determine the effects of irrigation methods on growth and specific characters of the rice plant. Sen (37), in India, reported that standing water in the field during the first 2 or 3 weeks after planting is beneficial for tillering. Later on, however, a wet soil with no standing water favors tillering. Draining the field 3 weeks after transplanting also is conducive to tillering. Thereafter, continuous submergence of the plants suppresses the

Table 15. Comparison of single and split applications of an 80-40-0 fertilizer to varieties of different maturity, Rice-Pasture Experiment Station, 1950

Time of application	Yield of rough rice, pounds per acre		
	Century Patna	Bluebonnet	Rexoro
No fertilizer	1,831	2,122	2,252
One application—at planting	3,532	4,585	3,353
One application—4 to 6 weeks after planting	3,888	4,244	3,499
Two applications—at planting and 4 to 6 weeks after planting	4,066	4,601	3,629
Four applications—equally spaced from planting to preheading	4,180	3,937	3,434
Least significant difference[1]	397	318	279

[1] The difference in yield between any two treatments must equal or exceed the amount shown to give odds of 19 to 1 that such difference is real and not due to chance.

growth of tillers and supplies the soil moisture necessary for the flowering stages.

The amount of water used in irrigating rice is governed by several factors, such as the amount and distribution of rainfall; temperature, humidity and evaporation; kind of soil; and the watering practices followed by the individual grower. Rice requires more irrigation water in dry than in wet years because there is more evaporation. Sandy soils, such as the Katy and Hockley fine sandy loams, require more water than heavy soils, such as Beaumont clay and Lake Charles clay, because of greater losses by percolation and seepage.

Cheng and Pien (12), in reviewing the literature on water requirements of rice in the rice-growing countries of the world, reported that the amount of water used ranged from about 24 inches in certain provinces of China to as much as 140 inches in California. Jones, Davis and Williams in California (21) state, however, that "basing water charges on the volume delivered rather than charging a flat rate per acre would tend to conserve water and to confine rice growing to the heavy soils, on which 4 to 8 acre-feet of water are required to produce a crop." According to Clayton (13), 24 to 30 inches of water, including rainfall and irrigation, are required to produce a crop of rice in Arkansas. Carter and Engler (9) also reported similar amounts for Arkansas. Gustafson (18) stated that 2 to 4 feet of water are used in Louisiana, depending on soil and weather conditions. About 40 to 45 inches of water are used for rice in an average season in Texas. Of this amount, rainfall supplies approximately 20 to 30 inches from May through October.

The amount of water needed for irrigating rice may be divided as follows: evaporation from the water surface of the rice field, transpiration of water by the rice plants, seepage of water through the soil, and initial applications of water to prepare the soil for planting, for flushing and to supply the water for the first submergence.

Irrigation Practices in Texas

Methods of irrigating rice in Texas depend to a large extent on the methods used in seeding. Where rice is seeded with the grain drill on heavy soils, the fields are usually flushed (irrigated) for germination if water is available and if the soil has not been saturated by rain. Flushing usually is practiced in areas irrigated from canals because fields can be covered much more rapidly from them than by irrigation from wells. Sandy soils and soils irrigated from wells usually are not flushed. Rice usually is irrigated for the first time when the plants reach a height of 4 to 6 inches. At this time, the irrigation water is applied to a depth of 1 to 2 inches and is gradually increased to 4 to 6 inches as the plants become taller, Figure 15. The irrigation water is held at a depth of about 5 inches during the remainder of the growing season until the land is drained prior to harvesting. Additional water is supplied from time to time to replace the water lost by evaporation, transpiration and seepage.

Irrigation water may be drained off once or twice during the growing season to permit fertilization and for the control of water weeds and insects. The time and number of drainings may vary, depending on the length of maturity of the variety, presence of weeds and insects and the supply of irrigation water. Fields that are not drained usually do not have sufficient water available for reflooding.

As indicated earlier, where rice is seeded with a grain drill, it sometimes is necessary to irrigate the land to germinate the seed. Where irrigation is required for germination, the field should be drained promptly because the seed are likely to rot if covered by soil and water. Where rice is seeded with an endgate seeder, the land is harrowed and irrigated. Then the irrigation water is drained off. The field is irrigated when the rice plants attain a height of 4 to 6 inches. Where rice is sown in water, some growers drain as soon as possible and others may delay draining as much as 36 hours. When the seedlings are up

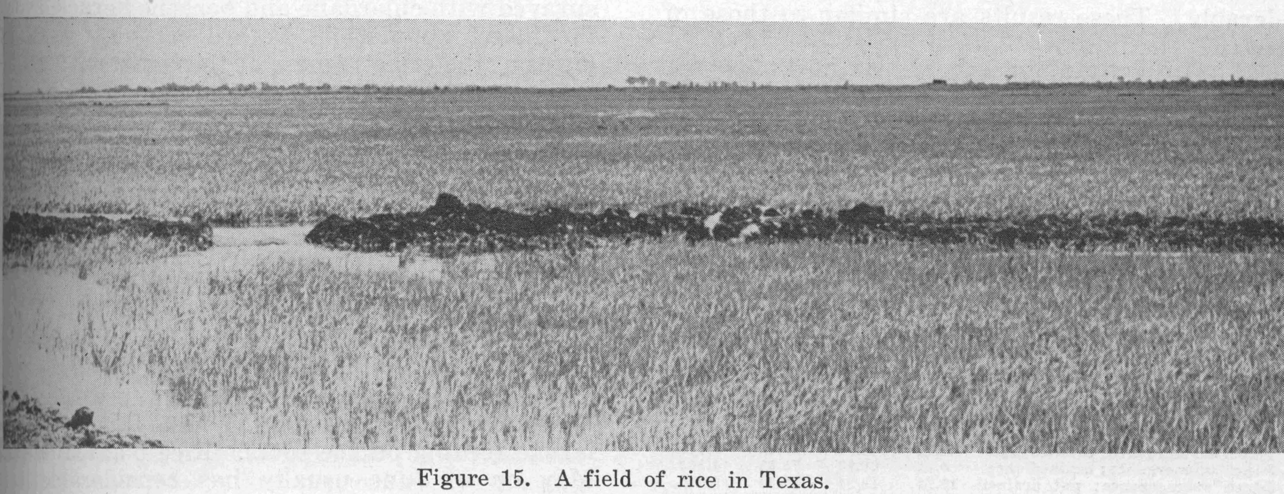

Figure 15. A field of rice in Texas.

and growing, the usual irrigation practice is followed.

Irrigation Experiments

The amount of water, including rainfall and irrigation, required to produce a crop of rice in Texas is common knowledge among rice growers. There is not, however, much specific information available on the irrigation requirements of rice, especially on the time and methods of irrigation. For this reason, experiments were started at Beaumont in 1952 to determine the effect of different watering practices on the yield and quality of rice, and to determine which practices might effect a saving in the amount of water used in producing the crop (31). The treatments used and amounts of water applied are shown in Table 16.

Bluebonnet 50 rice was drilled in 6 rows, 8 inches apart in each plot, on May 27. Fertilizer was drilled with the seed at the rate of 80 pounds of nitrogen and 40 pounds of phosphoric acid per acre. Plots for treatments 3 through 6 were flooded 17 days after planting, and plots for treatments 3, 4 and 5 were drained 42 days after planting. Heavy rains occurred while they were being drained, and the soil did not become dry enough to crack until 17 days later, at which time the plots were reflooded.

There was not much difference in the yields of rice where the total amount of water ranged from 46.34 inches to 73.01 inches. It appears, however, that the use of 45 to 50 inches of water would be just as satisfactory as larger amounts. These results are in general agreement with those reported by Jones, Dockins, Walker and Davis (22).

These results, which are for 1 year only, indicate that submergence for part of the season at least is necessary for satisfactory yields of rice. The depth of water does not seem to be of much importance where weeds are not a problem. The results also indicate that draining rice fields once during the season increases the yield of rice considerably. These results are similar to those of Sen (37) in India.

DRAINAGE

Although rice is grown on land that is submerged 60 to 90 days during the growing season, good surface drainage is necessary for several reasons. It is needed for the preparation of a desirable seedbed. Adequate surface drainage permits prompt drainage of rice fields before harvest and aids in harvesting the crop by allowing the soil to dry and thus support heavy machinery used in harvesting, such as tractors, combines, grain carts and trucks. It is more difficult to harvest rice on poorly-drained than on well-drained fields. Drainage at specific stages of rice growth may aid in the control of certain diseases, especially straighthead.

Rice fields in Texas usually are drained preparatory to harvesting when the heads are turned down and beginning to ripen. This stage is about 2 weeks before the grain is mature. The time to drain, however, varies with the kind of soil, variety of rice and the efficiency of the drainage system.

Table 16. Yield of rice receiving different irrigation treatments, Rice-Pasture Experiment Station, 1952

Irrigation treatments	Water used, inches			Yield, pounds of rice per acre
	Rainfall	Irrigation	Total	
1. No irrigation after germination	10.71	2.27	12.98	None
2. Soil kept moist but not submerged	10.71	23.78	34.49	962
3. 2-inch submergence; drained once	4.11	42.23	46.34	3,896
4. 5-inch submergence; drained once	4.11	46.52	50.63	3,945
5. 8-inch submergence; drained once	4.11	68.90	73.01	4,163
6. 5-inch submergence; not drained	10.71	48.84	59.55	2,822

INSECTS

Several insects attack rice in Texas. Among these are the rice stinkbug, rice water weevil, grasshoppers, armyworms and a few others of less importance.

Experiments were conducted at several locations in the rice belt in 1951-52 to determine the effect of several organic insecticides on the control of the major rice insects (8). The insecticides tested included aldrin, benzene hexachloride, chlordane, DDT, dieldrin, octamethlpyrophosphoramide, potosan, Systox and toxaphene. The effectiveness of the insecticides was measured in small replicated plots and by observation of large rice fields sprayed by commercial operators.

Rice Stinkbugs

The rice stinkbug is the major insect pest attacking rice in Texas. It is responsible for most of the losses caused to the crop by insects. Yield and grade losses are caused by the stinkbug feeding on the developing grains. Seven insecticides were applied as water emulsion sprays, and the rice was sprayed when it had been fully headed for about 1 week. In the plots to be sprayed with chlordane and benzene hexachloride, the insect populations before spraying were so low that the effectiveness of these materials could not be measured. Results with the other insecticides are given in Table 17.

Stinkbugs were controlled with the following rates per acre: aldrin, 0.5 pound; dieldrin, 0.5 pound; DDT, 1.0 pound; and toxaphene, 1.5 pounds. Experiments in 1953 indicate that the dosage of dieldrin may be reduced to 0.25 pound per acre and still maintain good control.

Rice Water Weevils

Rice plants are injured by the feeding of the adult rice water weevil on the leaves, and by the larvae feeding on the roots. Rice planted late in May or in June usually has considerable leaf

Table 17. **Effect of organic insecticides applied as a spray on rice to control stinkbugs, 1952**

Material	Pounds per acre	Number of stinkbugs[1]		
		Before treatment	2 days after treatment	7 days after treatment
Aldrin	.25	75	37	9
Aldrin	.50	16	4	2
Dieldrin	.25	35	10	8
Dieldrin	.50	22	6	2
DDT	1.00	14	4	2
DDT	.50			
and BHC	.30	8	2	4
Toxaphene	1.50	43	18	6

[1] Total counts gathered in 60 sweeps of a 12-inch insect net.

damage caused by the feeding of the adult weevils. This damage can cause a reduction in stand if the rice is attacked in the seedling stage.

Rice water weevils were controlled by spraying with DDT at the rate of 1 pound per acre and with potosan at 14 ounces per acre. Aldrin and dieldrin applied as soil treatments at the time of seeding apparently had little effect on the number of rice water weevils.

The larvae of the water weevil were not controlled by treating the seed with Systox or octamethylpyrophosphoramide, or by applying the materials in the irrigation water at the rate of 3, 6 and 9 pounds per acre when the rice plants were 2 months old.

Well-timed drainage, before the weevil larvae can cut off the roots of the rice plants, has been recommended as a control measure.

Grasshoppers and Armyworms

Grasshoppers and armyworms cause some damage to rice. Grasshopper nymphs feeding on the flowering parts of the rice cause losses in yield. Adult grasshoppers feed on the stem below the head and cause premature drying and shattering of the grain, which also reduces the yield. Observations indicate that grasshoppers may be controlled by spraying with toxaphene, chlordane, aldrin and dieldrin. Armyworms causing leaf injury may be controlled with toxaphene.

DISEASES

Diseases are important in the economical production of rice in the Southern States. Although total percentage reduction in yield and quality is probably less than in the other cereal crops, certain diseases of rice may occur in epidemic proportions and cause severe losses in stands, yield and quality of rice.

Under adverse environmental conditions, rice stands often are severely reduced due to parasitic attack by various seed and soil-borne organisms, such as *Helminthosporium oryzae* Breda de Haan, *Sclerotium rolfsii* Sacc., *Rhizoctonia solani* Kuhn and others. Many of the seedlings attacked by these fungi do not emerge or, should they emerge, are frequently so weakened that they fail to develop into normal plants. The affected seedlings are discolored. Mycelial masses are observed often on the diseased seedlings. Chemical seed treatments, such as yellow cuprocide, Arasan and Spergon at the rate of 1 ounce per bushel and Ceresan M at one-half ounce per bushel, give considerable protection for the young seedlings and better assurance of satisfactory stands of rice (5, 17).

Stem Rot

Stem rot, *Leptosphaeria salvinii* Catt. and *Helminthosporium sigmoideum* var. *irregulare* Cralley and Tullis (14, 15), is an important fungus disease in certain rice-producing areas of the South. Both of these organisms cause stem rot. *Leptosphaeri salvinii* is the perfect stage for *Helminthosporium sigmoideum* as such. *Helminthosporium sigmoideum* var. *irregulare* is a form or var. of *Helminthosporium sigmoideum,* whose perfect stage has not been described. The disease causes lodging and light weight grain. Lesions first appear on the leaf-sheath, then on the culm's node and innernode near the waterline a month to 6 weeks before the plants head. The black, necrotic areas spread around the culm and inward into the culm tissue. Numerous black, spherical sclerotia develop inside the leaf-sheath and later in the culm. As the panicles fill, the stalks break over the diseased area. Early infection results in poorly-filled grains. The development of resistant varieties appears to be the most practical means of combatting the disease.

Helminthosporium Blight

One of the most widely distributed and serious diseases of rice in the Southern States is brown spot, which is caused by the fungus *Helminthosporium oryzae* Breda de Haan. Losses frequently are encountered in stand due to seedling blight, in yield due to leaf and culm infection, and in quality and yield by kernel infection (17). Circular to elongate brown lesions usually are the diagnostic symptoms of the seedling blight, culm and leaf-spotting phases of the disease. Depending on the variety, however, the necrotic areas are known to vary considerably in size, shape and color. The development of resistant varieties offers the best means of control.

Leaf Smut

Leaf smut, *Entyloma oryzae* H. & P. Sydow, also occurs on rice in the Southern States. The disease, however, is considered of minor importance. The small, linear, black spots which characterize the disease are found in abundance on the leaf-sheath, leaf and panicle branches. Some varieties appear to be resistant to the disease.

Narrow Brown Leaf Spot

Narrow brown leaf spot of rice, caused by *Cercospora oryzae* Miyake, also is widely distributed. This disease often causes yield losses in the more susceptible varieties of rice. The lesions are generally more abundant on the leaves, although spots on the sheath, culm and floral bracts may be present in heavy infections. The narrow reddish-brown to dark brown linear lesions on the leaves usually are easily distinguishable. Varietal resistance has minimized the effects of this disease (1, 20, 36).

Blast or Rotten Neck

Blast or rotten neck, *Piricularia oryzae* Cav., is a serious disease in the more humid rice-producing areas. Although apparently sporadic in its occurrence in Texas, Arkansas, Louisiana and Mississippi, the disease is of considerable importance in Florida. It attacks the leaves, culms and branches of the panicle, and the floral structures. When blast occurs in epidemic proportions, severe losses are encountered in the stand, yield and quality of rice. Lesions on the neck of the culm and on the panicle branches near the base of the panicle are the most conspicuous symptom. The lesions break the panicle and thus prevent kernel filling (17). Lesions on the leaves at first are rather circular with pale greenish-gray centers, later coalescing and turning brown. The older necrotic areas on the leaves are somewhat similar in appearance to *Helminthosporium* leaf spots. Severe infections result in the blighting of the entire leaf. The development of resistant varieties appears to be the most practical means of control.

White Tip

White tip, caused by a seed-borne nematode, *Aphelenchoides oryzae* Christie, is a serious disease of rice in the Southern States. Losses occur in the yield and quality of rice from diseased fields. Diagnostic symptoms of white tip usually are quite distinct. Affected plants generally are dwarfed and possess frayed, chlorotic-tipped, twisted leaves. Panicles of diseased plants are distorted and, when badly diseased, may be so tightly bound by the twisting of the leaves around the culm that they often fail to emerge from the boot. Grains from affected panicles are malformed and may be reduced to one-third the size of grains from a healthy plant. The disease can be controlled by treating the infested grains in hot water at a temperature of 130 to 140° F. for 15 minutes, soaking in a mercuric chloride solution (0.75 to 1 part per million) for 12 hours, or by applying a newly developed commercial nematocide, N-244 (40 percent wettable), 1¼ ounce per bushel, as a dust or slurry (5, 40, 41).

Kernel Smut

Kernel smut is caused by a fungus, *Keovossia horrida* (Tak.) Padwick & Azmatullah Khan, and is widely distributed. The disease ordinarily causes little loss in yield. The loss that is sustained with kernel smut infection occurs mainly in the milling operation. Here a smutted lot of rice may so discolor an otherwise high-grade lot that its market value is lowered. Smutted grains in the field often have a bluish, dull-gray cast, and black masses of fungus spores are conspicuous when the grains are broken. Infection time has not been demonstrated satisfactorily (33). Seed treatments have not given satisfactory results in the control of the disease. Breeding resistant varieties apparently is the best means for the control of the disease.

Straighthead

Straighthead is one of the most destructive diseases of rice in the Southern States. The disease apparently is nonparasitic and occurs on new rice land and on soils where large amounts of organic material are plowed under. Relatively large roots, without branches and root hairs, develop rather than the fine, well-branched, fibrous root system which characterizes the healthy rice plant. Leaves of affected plants are dark green and stiff. The florets often are aborted and do not fill. As a result, the panicle remains erect, hence the term "straighthead." The disease is prevented under most conditions by draining off the irrigation water just before the rice is in the boot and allowing the soil to dry thoroughly (39, 42).

WEED CONTROL IN RICE

The importance of weed control in rice fields is recognized by rice growers and research workers. Studies on weed control in rice were included in the first experimental work undertaken at the Rice-Pasture Experiment Station. Reports on this early work were made in 1916, 1918 and 1919 (26, 27, 28). The use of cultural methods for weed control was emphasized. At that time, suitable chemicals for the practical control of weeds were unknown.

Cultural practices and the controlled use of water still are the farmer's most practical means of control of both grasses and broad-leaf weeds in rice fields. Summer or fall plowing with several disking operations timed to kill weed seedlings before seeding rice is a basic step in producing clean stands of rice. Water planting, where feasible, puts the rice ahead of the grassy weeds. When the plants are in the seedling stage or they are still young, the judicious covering of the weeds with water kills many of them and does not injure the rice.

Chemical weed control may be used where weather or other factors have made it impossible to control weeds satisfactorily by cultural practices. Chemical control of weeds, however, should be regarded as a supplement to cultural practices. Formulations of 2,4-D or 2,4,5-T, *used in accordance with State laws,* can help control broad-leaf weeds in rice fields. Experiments have shown that these chemicals, even when applied at the recommended rates of ½ pound of acid equivalent per acre when the rice is 30 days old and older, will influence the growth of the rice plants. Rice in flower can be damaged easily and extensively by these hormone-type weed killers. Hence, *it is* imperative that care be used, not only because of the hazard to the other crop plants, but to the rice itself.

Best results may be anticipated by making the applications when the rice is 4 to 6 weeks old and the weeds are in a succulent or rapidly-growing condition. Rain within 4 hours after application may reduce the extent of weed kill. Rates of $\frac{3}{4}$ to 1 pound acid equivalent per acre may be used to advantage with limited injury to the rice plants where the weeds are numerous, particularly if the weeds are large and have developed woody characteristics. If adverse weather conditions, unavailability of airplane service or some other factor have made it impossible to apply the material at the ideal stage of rice growth, the chemical with some calculated injury still can be applied to good advantage in weedy fields until the plants have been in "boot" for a week. Where rice is well advanced in the "boot" stage of development and weeds are numerous, it is suggested that all attempts to control the weeds by chemicals be postponed until the rice is headed and the field moisture content of the grain is 24 percent or less, at which time defoliants may be used to kill the weeds and hasten uniform moisture loss in rice grains.

HARVESTING

Time of Harvesting

In general, rice should be harvested when the heads have turned down and the kernels in the lower parts of the heads are in the hard-dough stage. At this stage, the range in moisture content of the rice grains is about 20 to 27 percent. The kernels are fully developed and will mill well. Rice harvested before this stage is likely to have a high percentage of light, chalky kernels which do not mill well; that is, it does not turn out a high percentage of head and total milled rice. If harvested after this stage, there may be considerable loss in yield from shattering and loss from inferior milling quality because of checking of the grain.

Research at the Rice-Pasture Experiment Station with long, medium and short-grain varieties showed that the best milling quality and germination were obtained when rice was harvested at moisture contents ranging between 26 and 16 percent. McNeal (29), at the Arkansas Station, found that the best stage to harvest rice was when the moisture content was between 24 and 16 percent, depending on the variety and date of seeding. Where rice is to be harvested for seed, it is thought best to delay harvest until the average moisture content is down to about 18 percent.

Preharvest Chemicals

Some research has been done in Arkansas and Texas during the past 2 or 3 years to determine the value of spraying certain herbicides by airplane to get more uniform and faster drying of the grain.

The Rice-Pasture Experiment Station obtained an average reduction of 6 percent moisture in rice $3\frac{1}{2}$ days after the rice was sprayed (43). This figure was the average of two different chemical mixtures in Shell horticultural base oil. One of the chemicals was dinitro at 2 quarts in 8 gallons of solution per acre, with 2 gallons of oil being used in 40 gallons of spraying mixture to facilitate spread. The other chemical was sodium chloroacetate used at the rate of 8 gallons of solution per acre, with one-half gallon of oil being used in 40 gallons of spraying mixture. These results indicate that spraying may result in a more uniform moisture content of the combined rice. The spraying also would reduce weed seed and vegetation of high moisture content because all weeds are killed. As a result of the lower moisture content of the combined rice, the volume capacity of commercial rice dryers would be increased. Spraying with these herbicides did not appreciably affect germination.

In addition to this work on chemicals for accelerating maturation of rice (43), it has been shown that neither Dow defoliant nor Shed-A-Leaf used at the rate of 8 pounds per acre in 8 or more gallons of water per acre and applied either with ground equipment or by airplane, reduced the germination of rice. Tests with Century Patna 231 and Rexoro showed no evidence of injury to the milling quality of rice that had been treated with either Dow defoliant or Shed-A-Leaf, when used according to the manufacturer's recommendations. Satisfactory results cannot be expected if lower than recommended gallonages are used. In thick stands or where deeper penetration is desired, even higher gallonages must be used to get the desired even top kill.

Hinkle (19), at the Arkansas Station, reported somewhat similar results, using Niagrathal-W, sodium monachloroacetate and Shed-A-Leaf, each applied by airplane at the rate of 8 pounds per acre in 8 gallons of water. A long-grain variety was sprayed at an initial moisture content of 27.2 percent. After 8 days, the moisture content of this rice was 13.1 percent and that of the unsprayed rice was 19.6 percent.

Since rice-stubble fields usually are grazed by livestock, the practice of spraying rice with chemicals to hasten maturation of the grain has raised the question of whether the use of these chemicals would be dangerous to livestock. Beef cattle pastured for 30 days at Beaumont on rice-stubble fields sprayed with Dow and Shed-A-Leaf defoliants showed no ill effects.

Methods of Harvesting

Rice is harvested almost exclusively with self-propelled or tractor-drawn combines (Figure 16). The combines range in size from 6 to 14 feet. Self-propelled combines are used in open-

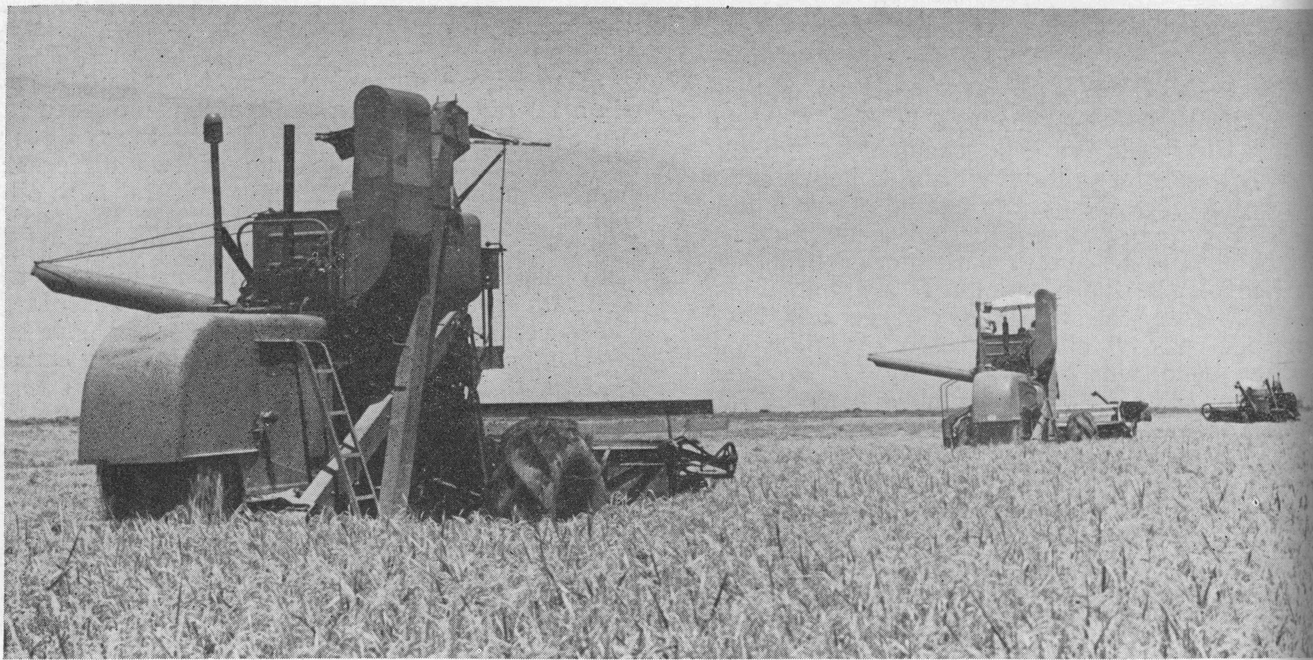

Figure 16. Harvesting rice in Texas with self-propelled combines.

ing up the field by cutting the first swath around the field and next to the levees in the subfields or "cuts." After this opening swath has been made, both types of combines are used in harvesting the remainder of the field.

In the process of harvesting, the rice is elevated into a bin or hopper on the combine. When the bin is filled, it is emptied into dump trucks and hauled to the dryer. When the field is soft, however, the bin is emptied into a rice cart mounted on rubber-tire wheels or crawler tracks, and hauled to firm ground.

When the combined rice arrives at the dryer, it is dumped into a receiving hopper and dried, as described in the section on drying.

DRYING AND STORAGE OF ROUGH RICE

Prior to 1941, rice in Texas was cut with a binder, then field-dried and threshed. In this method of harvesting, the moisture content was sufficiently low to permit the rice to be stored in burlap bags in flat storage.

The development of mechanical harvesting equipment during the past few years has completely changed the methods of harvesting and storing the rice crop. All of the rice in Texas is now harvested with combines. The rice is harvested in a short period of time and creates a serious problem of artificial drying and bulk storage.

The Rice-Pasture Experiment Station began experiments in 1947 to develop practical and economical methods of drying and storing rough rice.

At first, laboratory studies were conducted under controlled conditions of humidity, air velocity, temperature and milling technique to develop basic information that could be used in later studies on drying in commercial dryers (2). Air temperatures of 90 to 142° F. were used with relative humidities of 11 to 84 percent and air velocities of 100 to 200 cubic feet per minute (cfm). Zenith, Caloro, Bluebonnet and Rexoro varieties were used. There was no loss of milling quality in Bluebonnet and Rexoro at temperatures below 110° F. The loss at higher temperatures was increased by fast removal of moisture.

Bulk Drying

A brief summary of research results on drying rough rice in bulk and in sacks follows.

Column-type Dryers

Experiments were conducted on column-type dryers to determine the effects of drying at higher temperatures and rapid cooling of dried rice on

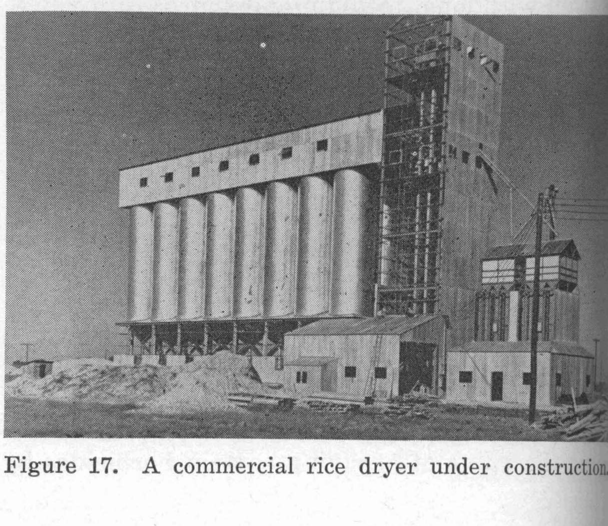

Figure 17. A commercial rice dryer under construction.

milling quality and germination (3). There was no significant difference in the milling quality of rice dried at 115.1 and 125.5° F. Rice was cooled rapidly as much as 32° F. without lowering its milling quality.

Air volumes up to 400 cfm per barrel were satisfactory and are now commonly used in commercial column-type dryers, Figure 17.

Drying in several stages is advantageous from the operator's standpoint. However, drying in one operation by continuous circulation of the rice through the dryer has not proved harmful when the rice temperature did not exceed 100° F. This method of drying is recommended for seed rice to prevent contamination or reduction in germination in the bins between dryings.

Stack-burned (heat-damaged), moldy and sour rice, or sour rice alone, can result from rice remaining too long in the tempering bin, especially after the first drying with a high moisture content (25).

Long-grain varieties dry faster than medium and short-grain varieties.

Bin Drying

Experiments on drying rice in bins were conducted at the Rice-Pasture Experiment Station in 1952-53 to determine the practicability of drying and storing rough rice on the farm (32). One 550-barrel lot of rice with a moisture content of 22 to 23 percent was not dried successfully at a depth of 10 feet with heated air at 115° F. supplied at a rate of 4.5 cfm per barrel. Another lot was dried from an average moisture content of 18 percent down to 12.2 percent in 7 days with a combination of heated and unheated air. This lot was dried at a depth of 6 feet with air supplied at a rate of 13.5 cfm per barrel.

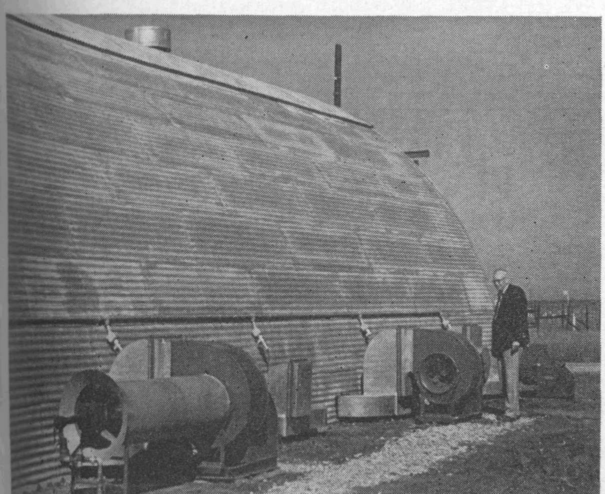

Figure 18. Exterior view of the building used in the tests on bin drying.

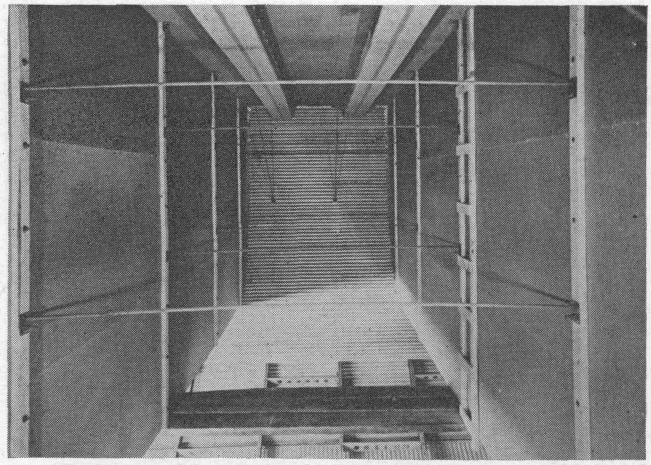

Figure 19. Interior view of a 500-barrel bin in the building used in the tests on bin drying.

Five lots of rice with initial moisture contents ranging from 15.9 to 21.1 percent were dried with unheated air. The rice was dried in 500 and 600-barrel bins at depths of 5.5 to 10 feet. Nine to 67 days were required to dry the rice to final moisture contents of 11.6 to 14.0 percent. Air was supplied at rates varying from 6 to 11 cfm per barrel. Bluebonnet, Century Patna and Rexoro varieties were used in these experiments. The rice was dried equally well whether the air was pushed or pulled through the rice, Figures 18 and 19.

Two series of tests were conducted in eight small bins to determine desirable air flow rates and the best operating procedure for unheated air drying. Based on the results of these tests, the minimum rate of air flow for an 8-foot depth of rice with 18 to 20 percent moisture is 7.5 cfm per barrel and a rate of 9 cfm per barrel is recommended. The recommended operating procedure is to push air through the rice continuously except when a rainy period lasts longer than 24 hours. During such periods, the fan should be operated 2 to 3 hours each day until the weather clears. This procedure should be continued until the moisture content of the top foot of rice is reduced to about 16 percent. Then the drying is completed by operating the fan only when the relative humidity is below 75 percent.

Sack Drying

Experiments on drying rice in sacks were conducted at the Rice-Pasture Experiment Station in 1947-52 (38), Figure 20. High milling yields of head rice and good germination were obtained at a maximum air temperature of 110° F. The bags of rice should be turned once during the drying operation for best results. Bluebonnet, a Patna type, Rexoro and Century Patna varieties were dried. There were no appreciable differences in the drying rates of the four varieties.

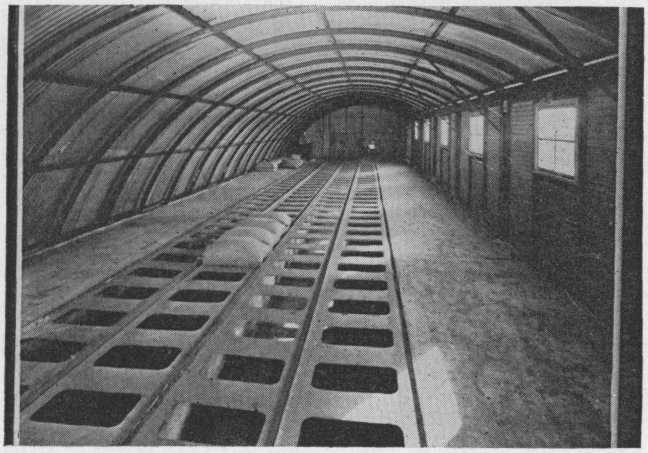

Figure 20. Drying seed rice in bags in a tunnel-type dryer at the Rice-Pasture Experiment Station. This method of drying prevents mechanical mixing of varieties.

The most efficient drying was done with rice in 110-pound bags, using 140 cfm per sack.

Sack drying is well suited for drying lots of seed rice, especially certified seed rice.

Air containing ozone had no advantage over atmospheric air in drying rice in sacks or in bulk.

Storage

Rice was stored satisfactorily in bins of wood, concrete and "Haydite" construction during cool weather for 1 to 4 months. Two lots of rice were stored in 20-barrel galvanized metal cisterns for 10 months without a change in the official grade and milling quality. The two lots of rice, however, had lost their germination and had increased in fat acidity.

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