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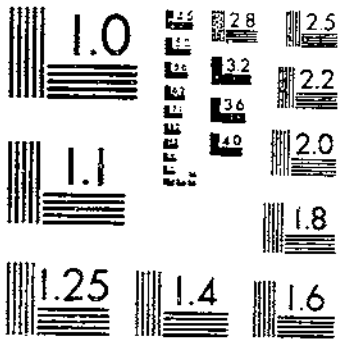

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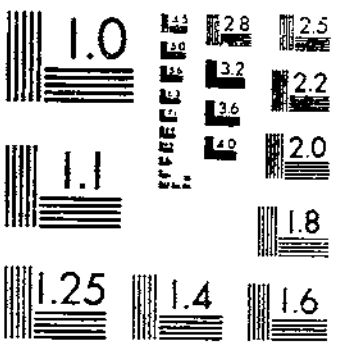

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Fertilizer Experiments With Rice in California[1]

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United States Department of Agriculture, Bureau of Plant Industry, in cooperation with the Agricultural Experiment Station of the University of California

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INTRODUCTION

The commercial rice crop of the United States is now produced in Louisiana, Texas, Arkansas, and California. In California it was first grown on a commercial scale in the Sacramento Valley in 1912.

During recent years the rice crop in California has ranged from 90,000 acres in 1924 to 160,000 acres in 1928, and the production from 4,365,000 bushels in 1924 to 10,150,000 in 1937. The average acre yield ranged from 46.5 bushels in 1925 to 70 bushels in 1937. The price of rough rice ranged from $0.36 per bushel in 1932 to $1.70 in 1925.

Rice is grown on submerged land during most of the growing season. The soils on which the crop is extensively grown lie in relatively level tracts that can be easily irrigated. Heavy soils that hold water well are preferred because they require less irrigation water to produce a crop. Most of the rice area now has fairly good surface drainage,

[1] Submitted for publication June 12, 1939.

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but the fields are not usually drained until in the fall shortly before harvest. Thus, rice is grown under aquatic or semiaquatic conditions most of the season, and for this reason fertilizers that increase the yields of other cereals on irrigated or nonirrigated land may be ineffective for rice grown on the same type of soil.

The yields of rice are comparatively high on virgin land in California, but on continuously cropped land marked decreases usually occur. Therefore, the crop is now largely grown on fallow or idle land in alternate years.

Fertilizer experiments were started at the Biggs Rice Field Station, Biggs, Calif., in 1914 and continued through 1919 to determine their effect on the yields of rice grown on relatively new land continuously cropped. In the 6-year period of 1914–19, marked increases in the average yields were obtained from the application of manure, ammonium sulfate, and dried blood, but superphosphate and potassium sulfate were not especially effective. Manure applied at the rate of 1 ton and ammonium sulfate at the rate of 100 pounds per acre gave the highest average yields and the highest net returns per acre. The data clearly indicated that nitrogen was the nutritive element limiting yields.

These results served as a basis for commercial fertilizer practice, and rice growers began to apply ammonium sulfate at the rate of 100 pounds per acre. Increased yields were obtained, but no information was available on the effect of higher rates of application on yields. After a lapse of 10 years it seemed advisable to determine also whether phosphorus and potassium fertilizers might be used to advantage on old riceland, even though they had not been especially effective on relatively new land. The experiments reported herein, therefore, were designed to obtain information on these problems, and to study the effect of some new commercial nitrogenous fertilizers on the yields of rice.

REVIEW OF LITERATURE

Reed and Sturgis (*20*)[2] and Sturgis [3] reviewed the literature dealing with the nutrition of the rice plant and with fertilization practices for rice in the United States and foreign countries. The results in this country only are mentioned here.

Quereau (*19*), in Louisiana, reported marked increases in the yields of rice from applications of superphosphate on reclaimed marshland. Later, Chambliss and Jenkins (*3*) found that the addition of dried blood, horse manure, and sulfate of potash increased yields on continuously cropped land, but the increases were not profitable. Ammonium sulfate, nitrate of soda, and cottonseed meal applied alone did not increase yields. The best results were obtained by growing rice in rotation with soybeans, from which the seed was harvested and the plants turned under. This practice also was recommended by Chambliss (*2*) in 1926. Jenkins (*6*) reported that during a 10-year period five fertilizer treatments increased yields on continuously cropped land, but the increases were not sufficient to cover the cost of the fertilizers and their application. The largest increase in yield

[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

[3] STURGIS, M. B. REVIEW OF RESULTS ON FERTILIZERS FOR RICE. La. Agr. Expt. Sta. Unnumb. Pub., 6 pp. [1934.] [Mimeographed.]

was obtained from a combination of ammonium sulfate and sulfate of potash applied at the rate of 200 pounds per acre. He suggested that better results might be obtained from the use of fertilizers on rice grown in rotation. Jenkins (*7*) also found that artificial manure applied at the rate of 4,000 pounds per acre on continuously cropped land did not increase the yield of rice materially.

Sturgis (*22*) reported that additions of leguminous organic matter increased the yield of rice in pot experiments on deflocculated Crowley silt loam soil, whereas the application of commercial fertilizers without the addition of organic matter was not effective. Sturgis and Reed (*23*) found that under controlled conditions in pot experiments the application of nitrogen to deflocculated Crowley silt loam soil increased the yield of rice and the percentage of protein in the heads. Phosphorus added to a soil deficient in this element also increased the yield of rice and resulted in a higher percentage of phosphorus in the heads. Reed and Sturgis (*20*) found that in laboratory and pot experiments large increases in the yield of rice were obtained from applications of leguminous organic matter. Additions of commercial fertilizers were less effective, but substantial increases in yields were obtained from materials that included phosphorus. Commercial fertilizers applied in a localized area around the seed were particularly effective.

Laude (*14*), in Texas, reported increased yields from applications of cottonseed meal, ammonium sulfate, superphosphate, and manure alone and in combinations. The most profitable increases were obtained with ammonium sulfate. Reynolds and Wyche (*21*) obtained larger average increases in yield from applications of ammonium sulfate than from superphosphate. Potash alone did not increase yields, but it was effective when applied with either phosphorus or ammonium sulfate. Ammonium sulfate applied at the rate of 100 pounds per acre gave a larger increase in yield in the first 8-year period than in the last 5-year period. The results of preceding years were confirmed in later reports (*24*). In cooperative tests ammonium sulfate on old riceland gave the best results, whereas on newer land superphosphate was most effective. In preliminary experiments, fertilizers applied with the seed gave larger increases in yields than when applied on the surface of the soil. Ammonium sulfate applied with the seed did not injure germination but cyanamide did. Little or no lateral movement of fertilizers applied on the surface of the soil was observed at Beaumont, Tex. (*24*).

Nelson (*15*), in Arkansas, reported very few increases in yield of rice from the application of fertilizers. The fertilizers stimulated the growth of weeds and grasses and the weed competition had a tendency to reduce yields. Yields of rice were not increased by the usual methods of fertilization on either grassy or relatively clean land. Some increases in yield were obtained by applying the fertilizers 3 or 4 weeks after seeding (*16*). In 1931 the experiments were changed so that the fertilizers used thereafter were largely free from basic materials and were applied before seeding, at seeding time, and 4, 6, 8, and 10 weeks after seeding (*17*). In subsequent years increased yields were obtained from applications of Ammo Phos Ko, Ammo-Phos, and ammonium sulfate applied 4 to 6 weeks or more after seeding. Substantial increases in yield of rice also have been obtained following such cover crops as Austrian Winter peas, hairy vetch, and clover

plowed under in the spring; also, following fallow, and soybeans in cultivated rows or in drills (*1, 18*).

Many laboratory and greenhouse experiments on the nutrition of rice also have been conducted in Arkansas. Janssen and Kapp (*5*) reported that ammonium sulfate caused a more rapid growth of rice seedlings than did nitrate fertilizers. In the same bulletin it was also reported that phosphate fertilizers should not be recommended under Arkansas conditions, because basic materials added in the irrigation water caused the soils to become nearly neutral or alkaline and this in turn caused soluble phosphorus to revert to forms unavailable for rice.

Kapp (*9*) believed that lack of available nitrogen was not responsible for abnormal growth and low yields of rice but later (*10, 11*) found that increased yields were obtained on dried and sterilized soil, which indicated that a lack of nitrogen was one factor responsible for the abnormal growth and low yields of rice frequently encountered. Kapp (*12*) reported that rice seedlings can be grown to maturity in solutions containing nitrogen in the form of either nitrates or ammonia but that the latter was slightly superior. Results also indicated that the growth of rice can be increased by the application of nitrogenous fertilizers plus acid treatments on nonacid rice soil. Rice growth and yields were increased by the application of acid to cropped rice soils. When the soil reaction was controlled, the addition of either basic or acidic nitrogenous fertilizers increased yields. The optimum soil reaction for rice grown in jars was pH 6.5 (*13*).

Jones (*8*), in California, reported increased yields from all fertilizers applied in the 3-year period 1914–16 except lime alone, and superphosphate and sulfate of potash in combinations. In the following 3 years fertilizers were applied alone and in combination at three stages of growth, (1) when the rice plants were about 3 inches high, (2) when the first panicles appeared, and (3) 2 weeks after first heading. The highest yields were obtained from the earliest application in nearly all cases.

The 6-year average increase in yields from fertilizers applied before seeding (1914–16) and when the plants were about 3 inches high (1917–19) was 1,046 pounds for manure, 707 pounds for ammonium sulfate, 628 pounds for dried blood, and 555 pounds per acre for ammonium sulfate, sulfate of potash, and superphosphate in combination.

Dunshee (*4*) reported average increases in rice yields of 645 pounds in 1925 and 1926 and 1,198 pounds per acre in 1927 from the application of 100 and 150 pounds of ammonium sulfate per acre to Willows clay soil in California.

Sturgis [4] reached the following conclusions from a review of the results of fertilizer experiments with rice in the United States:

1. The continuous culture of irrigated rice on soils low in organic matter or through which water drains very slowly causes the development of toxic or inhibitory conditions which lower the yield of rice. After such conditions develop, the simple application of commercial fertilizers will not be effective, but by draining the land and turning under legumes the yields of rice may be increased.

2. On soils in a good state of fertility or where inhibitory conditions have not seriously developed from the long continuous culture of rice, the application of from 100 to 200 pounds of ammonium sulfate would be expected to increase the yield of rice. In many cases the use of light applications of superphosphate with the ammonium sulfate would be of benefit. It is particularly significant to

[4] See footnote 3.

note here that the results from many of the fertilizer tests show that the highest yields were received during the earlier years of the experiment and that farmers were more successful with the use of fertilizers on rice when their soils were new to its culture.

3. From the experience of the past and from tests now under way, the best results from the use of fertilizers have been had on soils relatively well supplied with organic matter and in good physical condition, well aerated; and so long as such conditions of the soil are present, profitable results from fertilizers could be expected.

ENVIRONMENTAL CONDITIONS

Soil

The soil at the Biggs Rice Field Station is dark gray to black in color and is classified as Stockton adobe clay. It is sticky and waxy when wet and holds water well, but cracks readily when thoroughly dry and is difficult to till when either too wet or too dry. This soil is representative of a large part of the rice-growing section of California and the results obtained on the station are believed to be applicable in general to other sections of the Sacramento Valley in which rice is grown. The rice soils in California are often deficient in organic matter and nitrogen.

Temperature

The winters in the Sacramento Valley are comparatively cool, with some freezing weather. Spring is warm, and in summer the days are hot but the nights usually are comparatively cool. A daily range in temperature of 40° F. is not uncommon during the summer and early fall. Such wide daily ranges in temperature affect the development of the rice crop, and only the hardy varieties develop properly under such conditions.

The hottest months are June, July, and August with maximum temperatures of 100° F. or above each year. The highest temperature recorded during the 13-year period 1925–37 was 116° in July 1925, and the lowest 24° in April 1929. The extreme daily range in temperature for any one month was 56° in October 1929.

Precipitation

The average annual precipitation for the 13-year period 1925–37 was 18.48 inches, with an annual range from 11.28 to 30.09 inches. The highest precipitation occurred during December, January, and February. Often little or no rain falls during the growing season in July, August, and September. Heavy rains in October and November, the harvest season, may result in serious losses to rice growers.

Evaporation

The months of highest evaporation are June, July, and August. The average total evaporation from April 1 to October 31, inclusive, for the 13-year period 1925–37 was 39.29 inches.

The humidity during the growing season is low, and usually no injury to the crop is caused by fungus or other diseases.

METHODS USED

The rice was grown in $\frac{1}{10}$-acre plots 33 feet wide by 132 feet long. Each plot was enclosed by levees. From each $\frac{1}{10}$-acre plot one-

fifteenth of an acre was harvested to determine yields. The area harvested from each plot was protected on the sides and ends by a cropped area large enough to eliminate border effect. Each fertilizer or fertilizer combination was applied in duplicate or in three or four systematically replicated plots.

The preparation of the seedbed, the application of the fertilizers, the date and rate of seeding, and the time and method of irrigation were the same each year for all plots within an experiment.

Seedbed preparation consisted of spring plowing, followed by disking and dragging. The fertilizers were broadcast on the soil just before seeding. The seed also was sown broadcast on the surface of the soil at the rate of 150 pounds per acre. After seeding, the plots were submerged and the water was maintained at a depth of about 6 inches until the land was drained just before harvest. Barnyard grass (*Echinochloa crusgalli* (L.) Beauv.), the most troublesome weed in California rice fields, is successfully controlled by this method of irrigation. The rice thus germinates under water, and the seedlings come up through the water.

The rice was grown in alternate years either on fallow or idle land. The fallowed land was plowed in the spring and left rough until the following spring. It was then plowed again and prepared for seeding. The idle land received no cultivation until the seedbed was prepared by plowing, disking, and dragging just before seeding. If the land is not infested with weeds, it appears to recuperate equally well when left idle as when fallowed.

EXPERIMENTAL RESULTS

The fertilizer experiments herein reported include the effect on the yield of rice of (1) ammonium sulfate applied at different rates, (2) superphosphate and potassium sulfate applied singly and in combination with and without ammonium sulfate, and (3) some of the newer nitrogenous fertilizers applied at different rates.

Rate of Application of Ammonium Sulfate for Caloro Rice

An experiment was begun in 1925 to determine the effect on the yields of the midseason rice variety Caloro of applying ammonium sulfate at rates of 100, 150, and 200 pounds per acre. These weights contained 21, 31.5, and 42 pounds of nitrogen per acre, respectively. The common powder form of ammonium sulfate was used from 1925 to 1933, inclusive, and the granular form thereafter. Both forms contained 21 percent of nitrogen. The granular form can be applied more easily and uniformly with existing rice-seeding equipment and methods and is preferred by most growers.

From 1925 to 1931, inclusive, each fertilizer treatment and the check plot were replicated four times, and from 1932 to 1937, inclusive, three times. During the first 7-year period the experiment was conducted on the original station grounds, and in the second 6-year period, on the adjacent Armstrong tract, which was acquired later. The soil type was the same on both areas, but fewer rice crops had been grown on the station and the land was more productive than on the Armstrong tract.

The yields of rice from 1925 to 1937, inclusive, are given in table 1.

TABLE 1.—*Yields of Caloro rice on land fertilized with ammonium sulfate at different rates*

Fertilizer treatment	Rate of application	Yield per acre												
		1925	1926	1927	1928	1929	1930	1931 [1]	1932	1933	1934	1935	1936	1937
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Check (not fertilized)		4,001	3,240	3,008	3,889	3,236	4,421	4,444	3,224	2,957	2,502	3,574	3,211	4,758
Ammonium sulfate	100	4,335	3,645	3,998	4,301	3,773	4,732	5,130	3,835	3,885	3,225	4,485	3,715	6,005
	150	4,556	3,850	4,553	4,601	4,286	5,261	5,666	4,120	3,825	3,885	4,525	4,435	5,720
	200	4,399	3,919	4,688	4,755	3,889	5,516	5,145	4,615	3,795	3,765	5,025	4,125	6,290

Fertilizer treatment	Rate of application	Average yield per acre									
		13-year period (1925–37)	Increase		7-year period [2] (1925–31)	Increase		6-year period [3] (1932–37)	Increase	
	Pounds	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)		3,574			3,748			3,371		
Ammonium sulfate	100	4,236	662	18.5	4,273	525	14.0	4,192	821	24.4
	150	4,561	987	27.6	4,683	935	24.9	4,418	1,047	31.1
	200	4,610	1,036	29.0	4,616	868	23.2	4,603	1,232	36.5

[1] Station land.
[2] Armstrong tract.

The average increases in yield in the 7-year period (1925–31) on the more fertile station land were less for each rate of application than those for the 6-year period (1932–37) on the less fertile Armstrong tract. Apparently this was due to the fact that the average yield of the check plots for the 7-year period on station land was considerably higher than on the Armstrong tract, hence large increases were less easily obtained.

The fertilized plots on both areas produced higher average yields than the check plots each year. The yields from the 100-pound rate of application exceeded those from the 150-pound rate in only 2 of the 13 years, but in 6 years the yields from the 150-pound rate were higher than those from the 200-pound rate. The average increase for the 200-pound rate was only 49 pounds per acre more than for the 150-pound rate.

The plots fertilized at the 150-pound rate for the 13-year period yielded an average of 4,261 pounds per acre. Yields higher than this are often difficult to obtain because of lodging, partial sterility, and late maturity. On soils of lower fertility and when lower-yielding varieties are grown, larger increases may be obtained from rates of application higher than 150 pounds.

The beneficial effect of ammonium sulfate appears to be due largely to a stimulation of the seedlings during the early stages of growth. Rice seedlings grow more rapidly and remain greener and more leafy on fertilized land. Observations and experiments indicate that a lack of available nitrogen probably is responsible for the poor color of rice plants during the so-called yellow stage of growth.

The average net returns for the three rates of application for the 13-year period and for the 6-year period (1932–37) are shown in table 2. In calculating the net returns, the actual average cost of the fertilizer and the average value of the rice produced for each period considered separately were used.

TABLE 2.—*Average costs and net returns per acre from applications of ammonium sulfate at different rates*

Fertilizer treatment	Rate of application	Average cost per acre of—			Total cost per acre	Increased yield per acre	Value of rice per hundredweight	Value of increased yield	Cost of producing 100 pounds of increased yield	Net return per acre
		Fertilizer	Application	Increased handling cost[1]						
	Pounds	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Pounds*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
13 YEARS (1925-37)										
Ammonium sulfate	100	2.53	0.65	3.31	6.49	662	1.91	12.84	0.98	6.35
	150	3.80	.65	4.94	9.39	987	1.94	19.15	.95	9.70
	200	5.06	.65	5.18	10.89	1,036	1.94	20.10	1.05	9.21
6 YEARS (1932-37)										
Ammonium sulfate	100	1.89	0.65	4.11	6.65	821	1.47	12.07	0.81	5.42
	150	2.84	.65	5.21	8.73	1,047	1.47	15.39	.83	6.66
	200	3.78	.65	6.16	10.59	1,232	1.47	18.11	.86	7.52

[1] Estimated at 50 cents per hundredweight for threshing, sacks, twine, storage, hauling, etc. This cost is much less when the crop is harvested with a combine.

The 150-pound rate gave the highest net return per acre and also the lowest cost ($0.95) to produce each 100 pounds of increase in yield. Ammonium sulfate applied at the rate of 150 pounds per acre returned about $2 for each $1 invested.

During the 6-year period, 1932–37, the average value of rough rice was less and the cost of fertilizers also less than for the 13-year period. In other words, low prices for rough rice reduced the value of the increase in yield and the net profit per acre, in spite of the lower cost of the fertilizer and greater response to fertilizer on this tract. The most profitable rate of application on the station tract was 150 pounds and on the Armstrong tract 200 pounds per acre.

The rice matured on essentially the same average dates on the fertilized and check plots, the 150- and 200-pound rates of application delaying the average maturity only 1 day.

Rate of Application of Ammonium Sulfate for Colusa Rice

An experiment was begun in 1927 to determine the effect of rate of application of ammonium sulfate on the yields of the early-maturing Colusa variety (C. I.[5] 1600). The rice was grown in alternate years on station land that had been idle or fallowed the preceding year. Each treatment was replicated four times.

The annual and average yields are shown in table 3. The largest average increase in yield was 1,370 pounds for the 200-pound rate of application. The fertilized plots gave consistent increases in yields each year. The largest increase in yield was obtained from

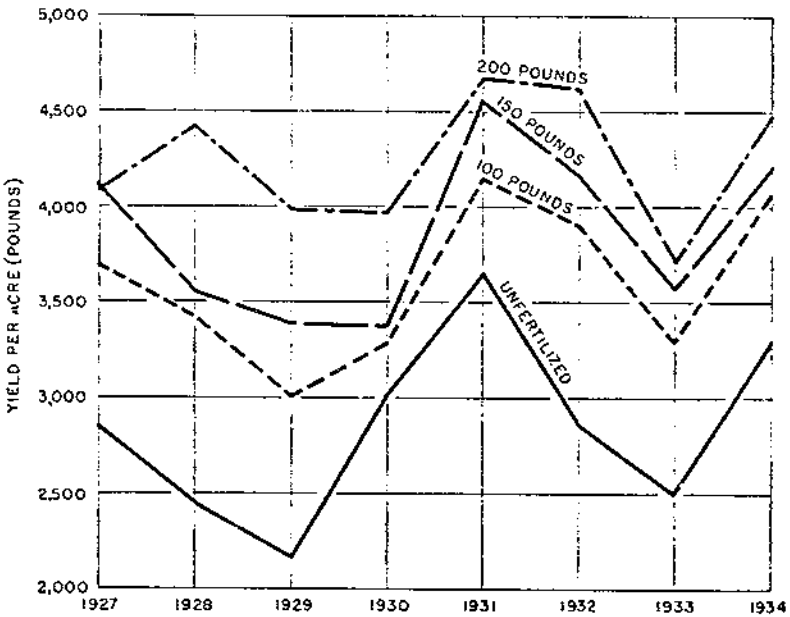

FIGURE 1.—Yields of Colusa (C. I. 1600) rice fertilized with ammonium sulfate at rates of 100, 150, and 200 pounds per acre, 1927–34.

[5] C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

the 200-pound rate each year except 1927, when a slightly higher yield was obtained from the 150-pound rate. The yields are shown in figure 1.

TABLE 3.—*Yields of Colusa rice grown on land fertilized with ammonium sulfate at different rates*

Fertilizer treatment	Rate of application	Yield per acre				
		1927	1928	1929	1930	1931
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Check (not fertilized)		2,854	2,475	2,195	3,049	3,641
Ammonium sulfate	100	3,694	3,439	3,015	3,296	4,159
	150	4,103	3,559	3,405	3,383	4,459
	200	4,080	4,421	3,980	3,964	4,665

Fertilizer treatment	Yield per acre				Average increase in yield per acre	
	1932	1933	1934	Average		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)	2,906	2,543	3,278	2,868		
Ammonium sulfate	3,911	3,300	4,069	3,610	742	25.9
	4,174	3,585	4,208	3,860	992	34.6
	4,613	3,765	4,478	4,238	1,370	47.8

The average net returns per acre for Colusa rice are shown in table 4. The most profitable rate of application was 200 pounds, whereas it was 150 pounds for the Caloro variety on similar land. Caloro matures later than Colusa and produces higher yields on old land. Colusa, however, yields well on virgin land and on fertile cropped land. The results indicate that the most profitable rate of application of ammonium sulfate depends on the variety grown and the fertility of the soil. Colusa, like the Caloro variety, matured on essentially the same dates on the fertilized and on the check plots.

TABLE 4.—*Average costs and net returns per acre from ammonium sulfate applied at different rates to Colusa rice (C. I. 1600)*

Fertilizer treatment	Rate of application	Average cost per acre of—			Total cost per acre	Average (1927–31)				
		Fertilizer	Application	Increased handling cost [1]		Increased yield per acre	Value of rice per hundredweight	Value of increased yield	Cost of producing 100 pounds of increased yield	Net return per acre
	Pounds	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Pounds*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Ammonium sulfate	100	2.53	0.65	3.71	6.89	742	1.71	12.69	0.93	5.80
Do	150	3.79	.65	4.96	9.40	992	1.71	16.96	.95	7.56
Do	200	5.05	.65	6.85	12.55	1,370	1.71	23.43	.92	10.88

[1] Estimated at 50 cents per hundredweight for threshing, sacks, twine, storage, hauling, etc.

TIME OF APPLICATION OF AMMONIUM SULFATE

Ammonium sulfate usually is applied at seeding time or before the land is submerged on commercial fields in California, because it can be applied more economically and satisfactorily at that time than

later. The rice plants often become light green in color and lacking in vigor in the early stages of growth. This condition usually is most noticeable 6 to 8 weeks after seeding or submergence. The unhealthy appearance of the seedlings during this period may be due in part to a lack of available nitrogen. In 1934 an experiment was begun to determine the effect on the yields of Caloro rice of applying ammonium sulfate at seeding time and after the seedlings had emerged. The plots of each treatment were replicated three or four times.

The fertilizer was applied at the rate of 150 pounds per acre at three stages: (1) At seeding time (usual practice), (2) at the tillering stage (about 55 days after seeding), and (3) at the first heading stage (about 100 days after seeding). The yields obtained are given in table 5.

The plants fertilized during the tillering and first heading stages turned dark green in color within 10 days after the ammonium sulfate was applied. No injury to the plants was observed. The application made at first heading delayed the maturity of the crop materially. The results indicate that it may be profitable to apply ammonium sulfate during the early stages of growth if the seedlings are yellowish in color and lacking in vigor. Ammonium sulfate in granular form can be applied easily to submerged fields at the desired time by the use of an airplane.

TABLE 5.—*Yields of Caloro rice grown on land fertilized with ammonium sulfate at different stages*

Time of fertilizer treatment	Yield per acre					Average increase in yield per acre	
	1934	1935	1936	1937	Average		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)	3,230	3,355	3,419	4,360	3,641		
At seeding (Apr. 29–May 11)	3,613	4,021	3,802	5,594	4,258	617	16.9
At tillering (June 26–July 7)	3,553	4,054	3,864	5,160	4,158	517	14.2
At first heading (Aug. 20–Sept. 3)	3,170	3,969	3,452	4,456	3,762	121	3.3

EXPERIMENTS WITH SUPERPHOSPHATE AND POTASSIUM SULFATE

Applications of superphosphate and potassium sulfate in earlier experiments (7) did not materially increase the yields of rice. These results, however, were obtained on land that had been cropped to rice for only a few years. After a lapse of 10 years it seemed advisable to start experiments again with these materials and ammonium sulfate. The superphosphate used contained 16 percent of phosphoric acid, the potassium sulfate 48 percent of potassium oxide, and the ammonium sulfate 21 percent of nitrogen. Phosphoric acid, potash, and the ammonium ion are fixed by the soil and are, therefore, resistant to loss by leaching. Ammonia, under normal soil conditions, however, is gradually oxidized to the nitrate form which is subject to leaching. On submerged land, however, conditions are unfavorable for the oxidization of ammonia; therefore it is a suitable form of nitrogen for the fertilization of riceland. The rice was grown in duplicated or replicated plots in alternate years on fallow or idle station land. The fertilizers were applied broadcast singly or in combinations just prior to seeding. The yields are shown in table 6.

TABLE 6.—*Yields of Caloro rice grown on land fertilized with ammonium sulfate, potassium sulfate, and superphosphate*

Fertilizer treatment	Rate of application	Yield per acre					
		1929	1930	1931	1932	1933	1934
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Check (not fertilized)		2,980	4,605	4,000	3,411	3,500	4,010
Ammonium sulfate	150	4,286	5,231	5,666	4,159	4,470	5,183
Potassium sulfate	120	2,755	4,027	4,135	3,503	4,035	3,998
Superphosphate	350	2,855	4,290	3,855	3,386	4,058	4,058
Ammonium sulfate	150	3,525	5,141	4,705	4,410	5,003	4,680
Potassium sulfate	120						
Ammonium sulfate	150	3,690	4,504	4,630	3,986	4,680	5,033
Superphosphate	350						
Potassium sulfate	120	3,645	4,125	4,268	3,769	4,035	4,568
Superphosphate	350						
Ammonium sulfate	150	4,135	4,886	5,000	4,380	4,575	5,228
Potassium sulfate	120						
Superphosphate	350						

Fertilizer treatment	Rate of application	Yield per acre				Increase in yield per acre	
		1935	1936	1937	Average		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)		3,915	4,268	5,190	4,007		
Ammonium sulfate	150	4,823	5,288	5,970	5,012	1,005	25.1
Potassium sulfate	120	4,538	4,470	4,650	4,012	5	.1
Superphosphate	350	4,598	5,314	4,806	4,202	195	4.9
Ammonium sulfate	150	4,740	5,786	5,978	4,892	885	22.1
Potassium sulfate	120						
Ammonium sulfate	150	5,040	5,906	5,723	4,866	859	21.4
Superphosphate	350						
Potassium sulfate	120	4,655	4,763	4,763	4,289	282	7.0
Superphosphate	350						
Ammonium sulfate	150	4,605	6,131	5,505	4,938	931	23.2
Potassium sulfate	120						
Superphosphate	350						

Potassium sulfate and superphosphate applied singly or in combination failed to increase yields materially. These results (table 6) indicate that nitrogen is the principal element limiting yields on the station land. Apparently sufficient available phosphorus and potash are present in this soil to produce relatively high yields of rice.

The average profit or loss from the application of the three fertilizers is given in table 7. The average net return from the addition of ammonium sulfate was $6.73 per acre. Superphosphate and potassium sulfate applied singly and together and both applied in combination with ammonium sulfate resulted in average net losses ranging from $2.83 to $5.94 per acre. Ammonium sulfate applied with superphosphate and with potassium sulfate gave negligible profits owing to the greater costs of the relatively expensive phosphorus and potassium fertilizer materials that did not materially increase yields. The average increase in yield from application of ammonium sulfate alone, however, was distinctly profitable.

TABLE 7.—*Average costs and net profits or losses from fertilizers applied during the 9-year period 1929–37*

Fertilizer treatment	Rate of application	Average cost per acre of—			Total cost per acre	Average (1929–37)				
		Fertilizer	Application	Increased handling cost [1]		Increased yield per acre	Value of rice per hundredweight	Value of increased yield	Cost of producing 100 pounds of increased yield	Net profit or loss per acre
	Pounds	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Pounds*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Ammonium sulfate	150	3.17	0.65	5.03	8.85	1,005	1.55	15.58	0.88	+6.73
Potassium sulfate	120	3.36	.65	.03	4.04	5	1.55	.08	80.80	−3.96
Superphosphate	350	4.24	.65	.96	5.85	195	1.55	3.02	3.00	−2.83
Ammonium sulfate	150	6.53	1.30	4.43	12.26	885	1.55	13.72	1.39	+1.46
Potassium sulfate	120									
Ammonium sulfate	150	7.41	1.30	4.30	13.01	859	1.55	13.31	1.51	+.30
Superphosphate	350									
Potassium sulfate	120	7.60	1.30	1.41	10.31	282	1.55	4.37	3.56	−5.94
Superphosphate	350									
Ammonium sulfate	150	10.77	1.95	4.66	17.38	931	1.55	14.43	1.87	−2.95
Potassium sulfate	120									
Superphosphate	350									

[1] Estimated at 50 cents per hundredweight for threshing, sacks, twine, storage, hauling, etc.

EXPERIMENTS WITH NEW COMMERCIAL NITROGENOUS AND OTHER FERTILIZERS

Many relatively new nitrogenous and other fertilizers are now on the market. An experiment was begun in 1932 to compare some of these products with ammonium sulfate, which is in general use in the California rice section. The land used in these experiments consisted of ninety $\frac{1}{10}$-acre plots, located on the Armstrong tract, from which $\frac{1}{15}$-acre plots were harvested for yield. The arrangement of the plots, the fertilizers used, and the amount of nitrogen added per acre are shown in figure 2. Each fertilizer was applied at such rates that 21, 31.5, and 42 pounds of nitrogen per acre were added, which were equivalent to the nitrogen in 100, 150, and 200 pounds of ammonium sulfate. Six check plots were included along with each rate of application. Two adjacent fields separated by only a 32-foot road and a drainage ditch were used, and the crop was grown in alternate years on idle or fallow land. Identical plot arrangements were used on each field. From 1914 to 1931 the entire area had been sown to rice largely in alternate years. The composition of the fertilizers applied is given in table 8.

	SERIES 1	SERIES 2	SERIES 3	SERIES 4	SERIES 5	SERIES 6
REPLICATION 3	CYANAMIDE 42	AMMONIUM SULFATE 42	AMMO PHOS KO 31.5	CALUREA 31.5	AMMO-PHOS 21	UREA 21
	AMMO PHOS KO 42	UREA 42	AMMO-PHOS 31.5	LEUNASALPETER 31.5	LEUNAPHOS 21	CHECK
	AMMO-PHOS 42	CHECK	LEUNAPHOS 31.5	AMMONUM SULFATE 31.5	CHECK	LEUNASALPETER 21
	LEUNAPHOS 42	CALUREA 42	CHECK	UREA 31.5	CYANAMIDE 21	AMMONIUM SULFATE 21
	CHECK	LEUNASALPETER 42	CYANAMIDE 31.5	CHECK	AMMO PHOS KO 21	CALUREA 21
REPLICATION 2	AMMO PHOS KO 31.5	UREA 31.5	AMMO-PHOS 21	CALUREA 21	LEUNAPHOS 42	LEUNASALPETER 42
	AMMO-PHOS 31.5	CHECK	LEUNAPHOS 21	LEUNASALPETER 21	CHECK	AMMONIUM SULFATE 42
	LEUNAPHOS 31.5	CALUREA 31.5	CHECK	AMMONIUM SULFATE 21	CYANAMIDE 42	UREA 42
	CHECK	LEUNASALPETER 31.5	CYANAMIDE 21	UREA 21	AMMO PHOS KO 42	CHECK
	CYANAMIDE 31.5	AMMONIUM SULFATE 31.5	AMMO PHOS KO 21	CHECK	AMMO-PHOS 42	CALUREA 42
REPLICATION 1	AMMO-PHOS 21	CHECK	LEUNAPHOS 42	LEUNASALPETER 42	CHECK	AMMONIUM SULFATE 31.5
	LEUNAPHOS 21	CALUREA 21	CHECK	AMMONIUM SULFATE 42	CYANAMIDE 31.5	UREA 31.5
	CHECK	LEUNASALPETER 21	CYANAMIDE 42	UREA 42	AMMO PHOS KO 31.5	CHECK
	CYANAMIDE 21	AMMONIUM SULFATE 21	AMMO PHOS KO 42	CHECK	AMMO-PHOS 31.5	CALUREA 31.5
	AMMO PHOS KO 21	UREA 21	AMMO-PHOS 42	CALUREA 42	LEUNAPHOS 31.5	LEUNASALPETER 31.5

FIGURE 2.—Plot arrangement of the experiment with new commercial nitrogenous fertilizers from 1932 to 1936, inclusive, at Biggs Rice Field Station. The number given in each plot represents the amount of nitrogen applied per acre.

TABLE 8.—*Composition of the fertilizers used in experiments of 1932–36*

Fertilizer	Nitrogen	Phosphoric acid (P_2O_5)	Potash	Remarks
	Percent	*Percent*	*Percent*	
Ammo Phos Ko [1]	12	24	12	A complete fertilizer.
Aero cyanamide [2]	21.5	.....	.....	A synthetic nitrogenous fertilizer containing considerable lime.
Leunaphos	20	20	.....	A mixture of diammonium phosphate and ammonium sulfate.
Ammo-Phos	16	20	.....	Largely a mixture of ammonium phosphate and ammonium sulfate.
Urea	45	.....	.....	A white crystalline organic compound.
Ammonium sulfate	21	.....	.....	A salt resulting from the interaction of ammonia and sulfuric acid.
Leunasalpeter	26	.....	.....	A double salt of ammonium sulfate and ammonium nitrate.
Calurea	34	.....	.....	A double salt of synthetic urea and calcium nitrate.

[1] Ammo Phos Ko was not obtainable in 1936, so Nitrophoska was used. The Nitrophoska contained 15 percent of nitrogen, 30 percent of phosphoric acid (P_2O_5), and 15 percent of potash. The rates of application of Ammo Phos Ko and Nitrophoska each supplied equal amounts of nitrogen per acre.

[2] Powdered cyanamide containing 30.5 percent nitrogen was used in 1932 and 1934.

The annual and average yields for the three rates of application are shown in table 9.

TABLE 9.—*Yields of Caloro rice grown on land fertilized at the rates of 21, 31.5, and 42 pounds of nitrogen per acre with different fertilizer materials, 1932–36*

21 POUNDS OF NITROGEN PER ACRE

Fertilizer treatment	Yield per acre						Average increase in yield per acre	
	1932	1933	1934	1935	1936	Average		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)	3,233	3,007	2,273	3,450	2,978	2,984	.....	.....
Ammonium sulfate	3,835	3,585	3,225	4,485	3,715	3,829	845	28.3
Ammo-Phos	3,560	3,705	3,625	4,350	3,755	3,799	815	27.3
Leunasalpeter	4,205	3,635	3,135	4,360	3,655	3,798	814	27.3
Urea	4,100	3,845	3,210	4,125	3,795	3,775	791	26.5
Ammo Phos Ko [1]	3,730	4,020	3,085	4,515	3,245	3,719	735	24.6
Leunaphos	3,480	3,710	3,250	4,370	3,670	3,696	712	23.9
Calurea	3,830	3,515	3,175	3,850	3,420	3,558	574	19.2
Cyanamide	3,525	3,495	2,770	4,120	3,385	3,459	475	15.9

31.5 POUNDS OF NITROGEN PER ACRE

Check (not fertilized)	3,235	3,198	2,768	3,728	3,395	3,265	.....	.....
Ammo-Phos	4,135	4,335	4,115	4,795	4,265	4,329	1,064	32.6
Leunaphos	4,280	3,990	4,180	4,550	4,455	4,291	1,026	31.4
Ammonium sulfate	4,120	3,825	3,885	4,625	4,435	4,158	893	27.4
Cyanamide	3,750	4,255	3,775	4,695	4,245	4,126	861	26.4
Ammo Phos Ko [1]	4,175	4,010	3,965	4,395	3,950	4,099	834	25.5
Leunasalpeter	4,595	3,965	3,915	4,680	3,645	3,980	715	21.9
Urea	3,660	3,800	3,825	4,230	3,655	3,832	567	17.4
Calurea	3,755	3,585	3,185	4,410	3,375	3,662	397	12.2

42 POUNDS OF NITROGEN PER ACRE

Check (not fertilized)	3,205	2,665	2,465	3,563	3,260	3,032	.....	.....
Leunaphos	3,985	4,590	4,185	4,735	4,720	4,443	1,411	46.5
Ammo Phos Ko [1]	4,085	3,715	4,465	4,900	4,795	4,374	1,342	44.3
Ammo-Phos	4,045	4,015	4,260	4,770	4,745	4,387	1,335	44.0
Ammonium sulfate	4,015	3,795	3,765	5,025	4,125	4,265	1,233	40.7
Leunasalpeter	4,425	4,090	3,860	4,730	4,135	4,208	1,176	38.8
Calurea	4,545	4,095	3,505	4,515	4,055	4,143	1,111	36.6
Urea	4,535	4,135	3,355	4,220	4,075	4,078	1,046	34.5
Cyanamide	3,870	3,225	3,525	4,090	4,745	3,951	919	30.3

[1] Nitrophoska used in 1936.

The average percentage increase in yields was higher from the higher rates of application, except for ammonium sulfate, Leunasalpeter, urea, and calurea applied at the 21- and 31.5-pound rates.

The 5-year average yields for all three rates of application are shown in table 10. The highest average yield for the three rates was 4,165 pounds for Ammo-Phos. Leunaphos and ammonium sulfate ranked second and third, respectively. Calurea gave the lowest average yield, which, however, was only slightly less than that of cyanamide.

TABLE 10.—*Five-year average yields of Caloro rice grown on land fertilized at three rates, 1932–36*

Fertilizer treatment	Average yield per acre from nitrogen applied at rate of—			Average		
	21 pounds	31.5 pounds	42 pounds	All rates	Increase in yield per acre	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)	2,984	3,265	3,032	3,094		
Ammo-Phos	3,799	4,329	4,367	4,165	1,071	34.6
Leunaphos	3,696	4,291	4,443	4,143	1,049	33.9
Ammonium sulfate	3,829	4,158	4,265	4,084	990	32.0
Ammo Phos Ko [1]	3,719	4,099	4,374	4,064	970	31.4
Leunasalpeter	3,798	3,980	4,208	3,995	901	29.1
Urea	3,775	3,832	4,078	3,895	801	25.9
Cyanamide	3,459	4,126	3,951	3,845	751	24.3
Calurea	3,558	3,662	4,143	3,788	694	22.4

[1] Nitrophoska used in 1936.

It is logical to use the fertilizer that returns the highest net profit per acre over a period of years. The most profitable fertilizer is the one that gives satisfactory increases in yields at the lowest cost per unit of increase. A more expensive fertilizer may give larger increases in yields than one less expensive but at a higher cost per unit of increase.

The 5-year average net profit or loss from the fertilizers applied at three rates are shown in table 11.

For the 21-pound rate of application the net return per acre ranged from $0.84 for Leunaphos to $5.75 for ammonium sulfate. Although Ammo Phos Ko materially increased yields, the increase was not sufficient to offset the high cost of the fertilizer and the result was an average loss of 40 cents per acre.

For the 31.5-pound rate of application the net return per acre ranged from $1.12 for urea to $5.28 for ammonium sulfate. Both Ammo-Phos and Leunaphos gave larger average increases in yield than did ammonium sulfate, but the profit per acre for Ammo-Phos was $4.53 and for Leunaphos $1.17 as compared with $5.28 for ammonium sulfate. The average increase in yield for Ammo Phos Ko was 834 pounds and for calurea 397 per acre, but owing to the high cost of these fertilizers they showed a loss of $2.90 and $1.33 per acre, respectively; thus, the profit or loss per acre depends on both the increase in yield and its cost. The fertilizer producing the largest increase in yield is not necessarily the most profitable on an acre basis.

TABLE 11.—*Average costs and net profits or losses per acre from fertilizers applied at three rates*

21 POUNDS OF NITROGEN PER ACRE

Fertilizer treatment	Average cost of—			Total cost	Average (1932–36)				
	Fertilizer	Application	Increased handling cost[1]		Increased yield	Value of rice per hundredweight	Value of increased yield	Cost of producing 100 pounds of increased yield	Net profit or loss
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Pounds*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Ammonium sulfate	1.88	0.65	4.23	6.76	845	1.48	12.51	0.80	+5.75
Leunasalpeter	2.17	.65	4.07	6.89	814	1.48	12.05	.85	+5.16
Ammo-Phos	3.50	.65	4.08	8.23	815	1.48	12.06	1.01	+3.83
Cyanamide	2.34	.65	2.38	5.37	475	1.48	7.03	1.13	+1.66
Urea	2.52	.65	3.96	7.13	791	1.48	11.71	.90	+4.58
Leunaphos	5.49	.65	3.50	9.70	712	1.48	10.54	1.36	+.84
Calurea	3.05	.65	2.87	6.57	574	1.48	8.50	1.14	+1.93
Ammo Phos Ko	6.95	.65	3.08	11.28	735	1.48	10.88	1.53	−.40

31.5 POUNDS OF NITROGEN PER ACRE

Ammonium sulfate	2.82	0.65	4.47	7.94	893	1.48	13.22	0.89	+5.28
Leunasalpeter	3.26	.65	3.58	7.49	715	1.48	10.58	1.05	+3.09
Ammo-Phos	5.25	.65	5.32	11.22	1,064	1.48	15.75	1.05	+4.53
Cyanamide	3.51	.65	4.31	8.47	861	1.48	12.74	.98	+4.27
Urea	3.78	.65	2.84	7.27	567	1.48	8.39	1.28	+1.12
Leunaphos	8.23	.65	5.13	14.01	1,026	1.48	15.18	1.37	+1.17
Calurea	4.57	.65	1.09	7.21	397	1.48	5.88	1.82	−1.33
Ammo Phos Ko	10.42	.65	4.17	15.24	834	1.48	12.34	1.83	−2.90

42 POUNDS OF NITROGEN PER ACRE

Ammonium sulfate	3.76	0.65	6.17	10.58	1,233	1.48	18.25	0.86	+7.67
Leunasalpeter	4.34	.65	5.88	10.87	1,176	1.48	17.40	.92	+6.53
Ammo-Phos	7.00	.65	6.68	14.33	1,335	1.48	19.76	1.07	+5.43
Cyanamide	4.68	.65	4.60	9.93	919	1.48	13.60	1.08	+3.67
Urea	5.04	.65	5.23	10.92	1,046	1.48	15.48	1.04	+4.56
Leunaphos	10.98	.65	7.06	18.09	1,411	1.48	20.88	1.32	+2.19
Calurea	6.10	.65	5.56	12.31	1,111	1.48	16.44	1.11	+4.13
Ammo Phos Ko	13.90	.65	6.71	21.26	1,342	1.48	19.86	1.58	−1.40

[1] Estimated at 50 cents per hundredweight for threshing, sacks, twine, storage, hauling, etc.

For the 42-pound rate of application the net return per acre ranged from $2.19 for Leunaphos to $7.67 for ammonium sulfate. Both Ammo-Phos and Leunaphos gave larger average increases in yields than did ammonium sulfate but were less profitable. Ammo Phos Ko gave an average increase in yield of 1,342 pounds but showed a loss of $1.40 per acre. Ammonium sulfate was the most profitable fertilizer at each rate of application. Ammo Phos Ko materially increased yields at all rates but showed a net loss of from $0.40 to $2.90 per acre. The net profit from applying ammonium sulfate at the rate of 100 (21 pounds of nitrogen) and 150 (31.5 pounds of nitrogen) pounds per acre was less than at the 200-pound (42 pounds of nitrogen) rate.

The average net profit per acre for the three rates of application ranged from $1.40 for Leunaphos to $6.23 for ammonium sulfate. Leunasalpeter ranked second and Ammo-Phos third, with average profits of $4.93 and $4.60 per acre, respectively.

Fertilizer Experiments with Caloro Rice in 1937

Leunaphos and Leunasalpeter were not available in 1937, so Cal-Nitro and anhydrous liquid ammonia (NH_3) were substituted. Cal-Nitro (ammonium nitrate mixed with calcium carbonate) contained 21 percent of nitrogen, half in the form of nitrate and the other half as ammonia, and also 33 percent of calcium carbonate. The anhydrous liquid ammonia contained 85 percent of nitrogen and was applied with the irrigation water at the time the land was first submerged. It required about 5 hours to submerge each 1/10-acre plot. The other fertilizers used were the same as in previous years. The results for 1937 are shown in table 12.

Table 12.—*Average yield of Caloro rice grown on land fertilized at three rates in 1937*

Fertilizer treatment	Average yield per acre [1] from nitrogen applied at rate of—			Average		
	21 pounds	31.5 pounds	42 pounds	All rates	Increase in yield per acre	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Check (not fertilized)	[2] 4,895	[2] 4,693	[2] 4,685	4,758		
Ammonium sulfate	6,005	5,720	6,290	6,005	1,247	26.2
Urea	5,845	5,510	5,715	5,690	932	19.6
Anhydrous liquid ammonia	5,710	5,585	5,615	5,637	879	18.5
Ammo-Phos	5,360	5,520	5,955	5,612	854	17.9
Nitrophoska	5,580	5,275	5,795	5,550	792	16.6
Calurea	5,295	5,395	5,920	5,507	749	15.7
Cal-Nitro	5,305	5,370	5,415	5,363	605	12.7
Cyanamide	4,930	5,285	5,835	5,350	592	12.4

[1] Average of 3 1/15-acre plots.
[2] Average of 6 1/15-acre plots.

The highest average yield of all rates, 6,005 pounds, was obtained from applications of ammonium sulfate; urea and anhydrous liquid ammonia ranked second and third. The average yield of the check plots was 4,758 pounds per acre, or 1,247 pounds less than for ammonium sulfate. Even though the average yields of the check plots were much higher than usual, marked increases in yields for all fertilizers were obtained. The average increase in yield ranged from 592 pounds for cyanamide to 1,247 pounds per acre for ammonium sulfate.

Effect of Turning Under Bur-Clover on the Yield of Rice

Volunteer bur-clover grows well in the rice section of California when climatic and soil conditions are favorable during the late winter and early spring months. Bur-clover serves as pasture for livestock and is often turned under as green manure on riceland.

It is difficult to get good stands of bur-clover on old riceland. In 1934 and 1936 an attempt was made to determine the effect of plowing under bur-clover on the yield of rice. In this experiment 36 1/10-acre plots were used and from each plot one-fifteenth of an acre was harvested to determine yields. Bur-clover was grown in alternate years on 26 of the 36 plots, and the other 10 plots served as checks. The stands of clover on the plots were estimated just before plowing

in the spring and varied from 10 to 95 percent. The growth of clover was good.

The yields from plots having stands of from 10 to 45 percent and those with stands of from 50 to 95 percent were averaged separately. The 2-year average acre yields of rice were 5,889 pounds on plots that had 10- to 45-percent stands of clover, 5,249 pounds on those having 50- to 95-percent stands, and 5,272 pounds for the check plot.

The lower yields on plots on which the clover stands were good and the growth heavy when turned under resulted chiefly from the excessive growth of the rice followed by partial sterility, uneven ripening, and lodging of the plants. The crop on such plots was also late in ripening. The yields of the check plots indicate that the land was of relatively high productivity, and it appears that turning under a heavy growth of bur-clover may be detrimental on such land. On less fertile land it is probable that a heavy growth of bur-clover would be beneficial. An increase over the check of 617 pounds per acre was obtained on the land on which a moderate amount of clover was turned under.

SUMMARY

Results of fertilizer experiments with rice at the Biggs Rice Field Station, Biggs, Calif., are presented.

The highest average yield of Caloro rice in the 13-year period 1925–37 grown on land fertilized with ammonium sulfate at the rate of 100, 150, and 200 pounds per acre was 4,561 pounds for the 150-pound rate, or an increase above the check of 987 pounds per acre. This rate of application also showed the highest net return, $9.76 per acre.

The highest average yield for the Colusa variety was obtained on land fertilized with ammonium sulfate at the rate of 200 pounds per acre. The 8-year (1927–34) average increase in yield was 1,370 pounds per acre, and the average net return was $10.88 per acre.

The application of ammonium sulfate at the rate of 150 pounds per acre at seeding time was more effective in increasing yields than when applied during the tillering or heading stages of growth.

The application of superphosphate and potassium sulfate alone and in combination failed to increase yields materially during the 9-year period 1929–37. Neither of these fertilizers nor both of them applied with ammonium sulfate gave larger increases in yield than when ammonium sulfate was used alone. The results indicate that nitrogen is the limiting element in this soil. Ammonium sulfate applied at the rate of 150 pounds per acre gave an average increase in yield of 1,005 pounds per acre and an average net return of $6.73 per acre. Superphosphate and potassium sulfate applied alone and in combination gave small average increases in yield and resulted in net losses of from $2.83 to $5.94 per acre.

Rice was grown for 5 years (1932–36) on land fertilized with ammonium sulfate, Ammo-Phos, Leunasalpeter, urea, Ammo Phos Ko, Leunaphos, calurea, and cyanamide at rates that added 21, 31.5, and 42 pounds of nitrogen per acre. Ammonium sulfate was the most profitable fertilizer in these experiments at each rate of application. Ammonium sulfate was also the most profitable fertilizer applied in 1937.

Plowing under a moderate growth of bur-clover in 1934 and 1936 resulted in increased yields of rice, whereas plowing under a heavy growth on land of high productivity reduced the average yield.

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