UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1387

Washington, D. C. ▼ March, 1926

EXPERIMENTS IN RICE CULTURE AT THE BIGGS RICE FIELD STATION IN CALIFORNIA

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CONTENTS

	Page
Introduction	1
Environmental conditions	3
Soil	3
Temperature	3
Rainfall	4
Wind	5
Evaporation	6
Experiments on the control of water grass and its varieties	7
Methods used	7
Experiments on immediate submergence after seeding	7
Comparison of air and water temperatures	11
Experiments on submergence immediately after the rice has emerged	12
Spring plowing and disking of stubble land compared	14
Experiments on the control of water grass and its varieties—Continued.	
Experiments on rate of seeding and method of irrigation	16
Experiments on seed-bed preparation	18
Rate-of-seeding experiments	19
Effect of variety	19
Yield data	20
Effect of continuous cropping on rice yields	21
Varietal experiments	23
Classes of rice	23
Varieties grown on tenth-acre plats	24
Varieties grown on small increase plats	28
Varieties following green-manure crops in 1924	29
Nursery experiments	30
Summary	36

INTRODUCTION

Water grass (*Echinochloa crusgalli*) is reported to be present in several important rice-producing countries of the world, but apparently in none of these countries has this grass become so troublesome as in California. This grass was present in California when rice growing first began, and in spite of efforts to keep it under control it has spread from year to year.

During the early growth of the rice industry in California the three factors most conducive to the rapid spread of water grass were plenty of available new land, tenant farming, and the method of irrigation. New land, land which had never been seeded to rice, was easily available, and because of the high acre yields obtained on such land it was eagerly leased by tenants, who often farmed large acreages and usually gave little attention to the rapid spread of water grass. When the land was fouled tenants moved to other new lands. The method of irrigation in use at that time also was favorable to the rapid spread of water grass. This consisted of irrigating and draining the land at frequent intervals until 30 days after the rice had emerged. The land was then submerged about 6 inches, and the water was held at about that depth until the fields were drained for harvest. Under

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this method of irrigation the land soon became foul. On such foul lands water grass competes successfully with the rice crop, and the reduced yields which follow are often unprofitable.

If the seed or seedlings of water grass are completely covered by water it is possible to smother this plant, whereas rice seed will germinate and emerge in a normal way even when fully submerged. This reaction of the two plants is the basis for control methods which are being developed and used on foul land.

The method most commonly used is to sow the rice on a well-prepared seed bed and to submerge immediately to a depth of 4 to 8 inches, maintaining this depth until the land is drained before harvest. A second method is to prepare the seed bed reasonably well, although not quite so thoroughly as in the first method, and to submerge the land to a depth of 4 to 8 inches. The rice is then sown broadcast in the water, which keeps it from being covered by the natural slaking of the soil in the water. Submergence is maintained until the land is drained before harvest. A third method less commonly used is to drill or broadcast the seed, with immediate irrigation. The land is then drained and so remains until both rice and water-grass seedlings have emerged, when water is turned on to a depth of 4 to 8 inches, where it is held until the land is drained for harvest. The first and second of these three methods are very effective in the control of water grass, the third being less satisfactory.

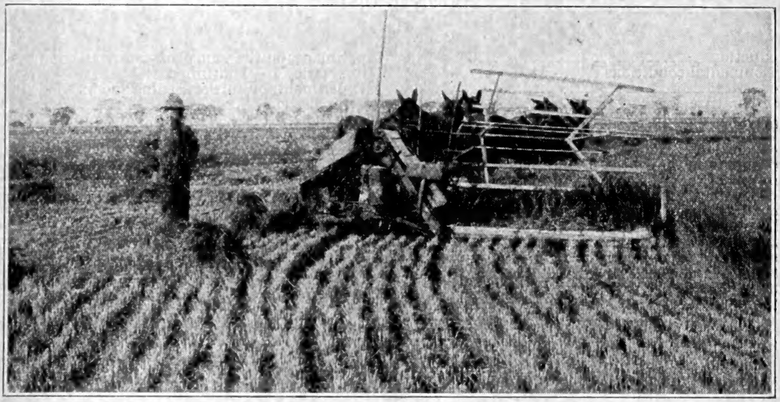

FIG. 1 —Harvesting scene in a commercial rice field near Biggs, Calif.

The acreage, acre yield, production, and farm value on December 1 of rice produced in California from 1912 to 1924, inclusive, are given in Table 1. These figures show a rapid increase in acreage from 1912 to 1920, inclusive, then a marked decline in acreage for 1921, a slight increase for 1922, then a marked decrease in acreage for 1923 and 1924. It is interesting to note the difference in value of the 1919 crop, grown on 142,000 acres, and the 1920 crop, grown on 162,000 acres. The reduction in value of nearly $10,000,000 shows how the rice growers were affected by the deflation in prices of farm crops. A harvesting scene in a commercial rice field near Biggs, Calif., is shown in Figure 1.

TABLE 1.—*Acreage, acre yield, production, and farm value of rice in California from 1912 to 1924, inclusive*

[Bushels of 45 pounds]

Year	Acreage	Production (bushels)		Farm value, December 1	Year	Acreage	Production (bushels)		Farm value, December 1
		Per acre	Total				Per acre	Total	
1912	1,400	50.0	70,000	$64,000	1919	142,000	55.5	7,881,000	$21,042,000
1913	6,100	48.0	293,000	293,000	1920	162,000	60.0	9,720,000	11,761,000
1914	15,000	53.3	800,000	800,000	1921	135,000	54.0	7,290,000	8,384,000
1915	34,000	66.7	2,268,000	2,041,000	1922	140,000	55.0	7,700,000	8,470,000
1916	55,300	59.0	3,263,000	2,545,000	1923	106,000	51.6	5,470,000	6,126,000
1917	80,000	70.0	5,600,000	9,800,000	1924[1]	88,000	50.0	4,497,000	7,465,000
1918	106,220	66.0	7,011,000	13,321,000					

[1] Preliminary estimate.

This bulletin describes the nature of the environmental conditions at the Biggs Rice Field Station, gives the results of experiments on watergrass control and rate of seeding, shows the effect of continuous cropping to rice, and discusses the varietal experiments conducted during the past few years.

ENVIRONMENTAL CONDITIONS[1]

SOIL

The soil at the Biggs Rice Field Station is Stockton clay adobe, dark gray to black in color. This soil is very sticky and waxy when wet and holds water well, but cracks badly when thoroughly dry and is very difficult to work when either too wet or too dry.

The soil at the station is representative of a large part of the rice-growing area in California, and the results obtained thereon are applicable in a general way to other sections of the Sacramento Valley in which rice is grown.

TEMPERATURE

The Sacramento Valley is subject to wide ranges of temperature. The winters are comparatively cool, with some freezing weather. The springs are warm and the summers are hot, though the summer nights are usually comparatively cool. A daily range in temperature of 40° F. is very common. These wide ranges in temperature between day and night affect the development of the rice crop, and only the hardier types of rice do well under such conditions. The fall is usually warm but seldom hot.

Table 2 presents data showing the maximum, minimum, and the extreme daily range in temperature, by months, from April 1 to October 31 during the 12-year period from 1913 to 1924, inclusive.

June, July, August, and September are the hottest months, with maximum temperatures of 96° F. or higher each year. The highest temperature recorded during this 12-year period was 112° F. in August, 1913. April and October are the coolest months for which data are recorded in the table. The lowest temperature recorded in April was 28° F. in 1917 and 1921; the lowest temperature recorded in October was 33° F. in 1919.

[1] Jones, J. W. Rice experiments at the Biggs Rice Field Station in California U. S. Dept. Agr. Bul 1155, 59 p., illus. 1923

TABLE 2.—*Temperature by months at the Biggs Rice Field Station from April 1 to October 31 for each year during the 12-year period from 1913 to 1924, inclusive*

[Data in ° F.]

Year	April	May	June	July	August	September	October
Maximum:							
1913	86	100	99	108	112	110	97
1914	84	100	107	110	107	99	93
1915	86	96	102	107	105	98	92
1916	84	87	102	105	104	96	81
1917	85	86	107	111	103	101	100
1918	87	88	110	103	105	90	89
1919	86	99	102	108	103	97	90
1920	91	95	107	104	106	99	86
1921	89	92	107	107	104	99	91
1922	86	98	109	108	103	103	89
1923	84	93	96	110	107	107	90
1924	90	99	104	102	104	102	88
Minimum:							
1913	31	40	47	53	53	47	38
1914	39	46	47	55	49	47	38
1915	40	40	54	55	56	47	40
1916	37	36	46	50	50	49	35
1917	28	39	47	56	55	45	37
1918	32	43	52	52	54	52	35
1919	36	43	50	51	52	47	33
1920	34	40	52	54	55	43	34
1921	28	31	50	53	53	49	37
1922	30	35	49	52	52	45	34
1923	36	42	49	54	52	43	37
1924	34	44	51	52	53	42	35
Extreme daily range:							
1913	40	46	48	50	46	48	52
1914	33	39	43	47	49	44	46
1915	37	34	41	40	44	40	45
1916	37	37	44	45	42	42	37
1917	39	39	43	44	43	43	46
1918	44	44	45	44	38	36	41
1919	36	41	46	43	41	42	47
1920	46	43	44	44	40	39	40
1921	45	39	41	43	41	43	42
1922	43	39	41	41	40	43	43
1923	38	38	39	41	42	42	43
1924	48	44	41	44	41	48	36

RAINFALL

Table 3 gives the monthly, average monthly, yearly, and average yearly precipitation for the 12-year period from 1913 to 1924, inclusive, at the Biggs Rice Field Station. The monthly and average monthly data are shown graphically in Figure 2.

TABLE 3.—*Precipitation by months at the Biggs Rice Field Station for the 12-year period from 1913 to 1924, inclusive*

[Data in inches; T=trace]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1913	3.51	0.79	1.11	3.16	1.39	0	0	0	0	0.20	6.67	8.28	25.11
1914	10.83	5.36	.54	1.59	.50	1.81	0	0	0	.89	.33	4.40	26.25
1915	7.60	9,04	2.03	.75	3.57	0	0	0	0	0	1.11	6.89	30.99
1916	10.24	3.43	.94	0	.25	.29	.37	0	.66	1.67	1.34	4.82	24.01
1917	2.44	4.75	1.28	1.41	.66	0	0	0	.55	0	1.58	1.26	13.93
1918	.78	4.22	5.36	0	.35	0	0	0	3.00	.66	2.61	1.71	18.69
1919	2.87	5.21	1.76	.08	.14	0	0	0	.98	.29	.64	2.73	14.70
1920	.31	1.93	3.67	.96	0	.14	.03	0	T	1.81	7.67	7.37	23.89
1921	4.74	1.48	1.83	.35	.74	.11	0	0	0	.91	2.19	5.14	17.49
1922	2.79	4.88	1.73	.42	.59	T	T	0	0	1.64	4.84	8.11	25.00
1923	2.66	.52	0	3.26	.57	.42	T	0	.96	1.06	.72	1.32	11.49
1924	2.55	3.67	1.22	.51	.06	0	0	T	T	3.49	1.63	5.52	18.65
Average	4.28	3.77	1.79	1.04	.74	.23	.03	0	.51	1.05	2.61	4.80	20.85

The average precipitation for the 12-year period from 1913 to 1924 was 20.85 inches. In 1913, 1914, 1915, 1916, 1920, and 1922 the precipitation was considerably above the average, while in 1917, 1918, 1919, 1921, 1923, and 1924 it was below the average. The months of greatest precipitation are December, January, and February.

Heavy continuous rain in October and November may result in serious losses to rice growers. In the fall of 1920 losses were heavy from November rains, which delayed threshing until spring, and in 1922 and 1924 rains during October and November interfered with harvesting operations and materially increased the cost of production.

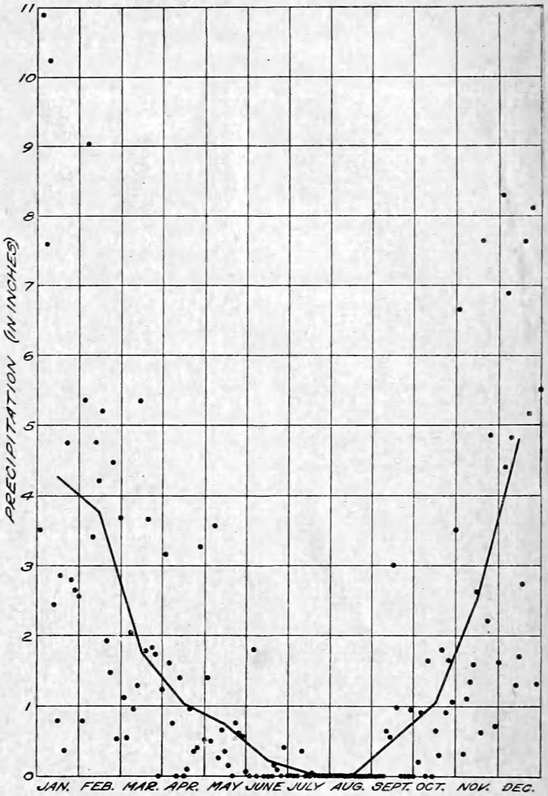

FIG. 2.—Monthly and average monthly precipitation at the Biggs Rice Field Station during the 12-year period from 1913 to 1924, inclusive

WIND

In general this section has but little wind, though strong winds sometimes blow from the north or the south. The strong north winds are known as "northers" and are especially welcome during the rice harvest because of their effective drying qualities.

Table 4 presents data showing the maximum, minimum, and average monthly wind velocity in miles per hour from April 1 to October 31 during the 12-year period from 1913 to 1924, inclusive.

TABLE 4.—*Monthly wind velocity at the Biggs Rice Field Station from April 1 to October 31 for each year during the 12-year period from 1913 to 1924, inclusive*

[Data in miles per hour]

Year	April	May	June	uly	gust	September	October
Maximum:							
1913	------	------	------	14.0	9.6	13.7	12.6
1914	7.1	11.0	12.0	7.5	7.1	13.2	8.7
1915	12.1	12.8	11.7	7.2	3.5	6.7	8.2
1916	12.4	11.3	9.7	8.1	8.7	6.9	9.7
1917	10.6	8.6	9.4	5.9	4.0	9.0	7.9
1918	15.7	8.5	5.8	9.5	5.9	4.9	5.3
1919	8.4	12.1	7.4	6.0	5.8	6.8	6.9
1920	16.1	8.7	8.7	7.9	5.8	5.6	5.7
1921	10.7	9.6	8.5	13.7	5.9	6.8	6.0
1922	10.9	10.1	7.0	4.0	4.4	4.0	6.3
1923	11.0	9.4	7.7	6.6	7.3	5.4	6.3
1924	10.2	9.8	7.5	5.8	7.9	9.3	7.5
Minimum:							
1913	------	------	------	1.1	.8	.6	.3
1914	.6	.4	.1	.4	1.0	1.5	.3
1915	1.4	1.8	.1	1.3	1.0	.6	.9
1916	.5	1.2	1.4	1.7	1.4	.9	.2
1917	1.3	1.8	.2	.2	.9	1.1	.6
1918	1.3	2.0	.6	.7	.4	.2	.1
1919	.7	.6	.8	------	.9	.4	.3
1920	.9	.9	.4	1.0	.5	.2	.1
1921	.9	1.0	.6	1.0	.8	.7	.3
1922	1.2	.8	.6	.3	.4	.1	.1
1923	.9	1.0	.7	.6	.6	.5	.1
1924	.9	.7	1.0	1.2	.6	.4	.6
Average:							
1913	------	------	------	5.1	4.2	3.9	4.1
1914	3.5	3.8	5.2	4.2	3.2	4.9	3.5
1915	4.9	5.3	4.3	3.2	2.1	2.2	2.3
1916	4.5	5.0	4.2	3.6	3.2	3.0	2.2
1917	5.2	4.5	4.1	2.4	2.3	4.0	2.7
1918	4.4	3.9	2.2	3.1	2.3	1.7	1.7
1919	3.2	2.9	3.9	3.2	2.5	2.8	3.2
1920	4.2	3.2	4.3	3.2	1.7	2.0	2.0
1921	3.9	3.6	3.4	3.0	2.4	2.4	1.6
1922	4.9	3.8	3.1	1.8	1.8	.9	1.6
1923	4.2	3.6	3.7	2.7	2.2	1.9	2.4
1924	4.1	3.8	4.3	3.1	2.4	2.4	2.7

EVAPORATION

Table 5 presents data on the monthly, average monthly, seasonal, and average seasonal evaporation from April 1 to October 31 for the 12-year period from 1913 to 1924, inclusive.

TABLE 5.—*Monthly and seasonal evaporation at the Biggs Rice Field Station from April 1 to October 31 during the 12-year period from 1913 to 1924, inclusive*

[Data in inches]

Month	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Average
April	------	3.840	3.383	------	4.091	------	------	4.363	5.243	4.947	4.425	5.205	------
May	------	5.789	4.996	7.161	6.119	[1] 6.970	------	[2] 3.845	5.853	5.945	6.707	7.431	------
June	9.120	7.348	8.500	9.261	9.448	12.224	8.991	7.160	7.052	6.843	7.227	[3] 7.149	8.455
July	11.216	8.263	9.618	9.270	10.110	8.679	9.692	7.104	9.076	6.932	8.866	8.406	8.936
August	9.247	6.775	7.825	8.152	8.178	7.035	7.858	6.227	7.845	6.495	7.275	6.435	7.446
September	8.767	5.760	5.912	6.279	6.158	3.946	5.497	4.691	4.956	4.324	5.672	[4] 4.593	5.656
October	6.221	3.003	4.466	2.713	------	4.480	4.256	2.793	2.879	2.542	3.870	------	------
Total:													
June to October	44.571	31.149	36.321	35.675	------	36.364	36.294	27.975	31.808	27.136	32.910	------	34.020
May to October	------	36.938	41.317	42.836	------	------	------	------	37.661	33.081	39.617	------	38.575
April to October	------	40.778	44.700	------	------	------	------	------	42.904	38.028	44.042	------	42.090

[1] Last 17 days of May.
[2] Last 18 days of May.
[3] 26 days in June.
[4] 23 days in September.

June, July, and August are the months of highest evaporation. The average evaporation for these three months for the 12-year period from 1913 to 1924, inclusive, was 24.834 inches. The average evaporation from June to October, inclusive, for the 11-year period from 1913 to 1923, with 1917 omitted, was 34.02 inches, with a range from 27.136 inches in 1922 to 44.571 inches in 1913.

EXPERIMENTS ON THE CONTROL OF WATER GRASS AND ITS VARIETIES

METHODS USED

The term "water grass" as used in this bulletin includes all forms of water grass (*Echinochloa crusgalli*) and its varieties except the white, or "Japanese," barnyard grass.

Experiments to control water grass by continuous submergence were started at the Biggs Rice Field Station in 1921. The results obtained in that year have been published.[2]

Experiments are being conducted at the station to determine, if possible, the best method of seed-bed preparation, date and rate of seeding, and date and depth of submergence for rice when grown by continuous submergence after broadcast seeding or when submerged soon after the rice emerges. These experiments were planned also to study the effect of the different irrigation methods on the control of water grass and on the yields of rice.

The work on water-grass control herein reported covers (1) experiments on immediate submergence after seeding, including the effect of sowing broadcast on the soil and in the water and the effect of drilling the seed; (2) experiments on depth of submergence after the rice has emerged, including a comparison of broadcasting and drilling seed and comparison of spring plowed and disked stubble land; (3) experiments on rate of seeding and method of irrigation; and (4) experiments on seed-bed preparation, including comparison of the effects of good preparation and poor or no preparation and the control of cat-tail by heavy seeding. In most of these experiments the dates of seeding and depth of submergence also were varied.

None of the rice sown broadcast was harrowed or covered after sowing. On plats submerged at specified depths the water was maintained at as near the depths stated as was possible under field conditions until the land was drained for harvest. All plats were sown at the rate of 150 pounds per acre unless otherwise stated. The few "Japanese," or white, barnyard-grass plants which appeared were hand pulled in all experiments, except those on seed-bed preparation.

During the crop years 1922 and 1924, the temperature was favorable for rice production, but during the crop year 1923 the temperature was apparently too cool for maximum yields of rice.

EXPERIMENTS ON IMMEDIATE SUBMERGENCE AFTER SEEDING

Experiments involving immediate submergence after seeding were conducted in 1922, 1923, and 1924 on land that had been continuously cropped to rice in the fertilizer experiments from 1913 to 1920,

[2] Jones, J. W. Op. cit

inclusive. In 1921 the land was fallowed. The 1922 crop, therefore, was the ninth rice crop in 10 years; the 1923 crop was the tenth rice crop in 11 years; and the 1924 crop was the eleventh rice crop on this land in 12 years. In the spring of 1922 the fallow land was double disked, harrowed, and dragged. For the 1923 crop the land was spring plowed, harrowed, and dragged. In preparation for the 1924 crop the land was winter plowed and the following spring double disked and dragged. Each year these tillage operations provided a reasonably good seed bed, but in the spring of 1924 considerable water grass was present from seed which had been germinated by the early spring rains. Many of these plants were not killed by double disking, and when the rice was sown and submerged a good deal of this grass was too large to be suffocated by water, and therefore it continued to grow with the rice crop.

EFFECT OF SOWING BROADCAST ON THE SOIL

In the experiments on the effect of sowing broadcast the rice was sown on the soil on different dates and the plats immediately submerged to the required depths. On plats submerged 2 inches considerable water grass emerged; on plats submerged 4 inches some water grass emerged; but plats submerged 6 and 8 inches were practically free from water grass and sprangletop (*Leptochloa fascicularis*) each year. Other water weeds appear to grow about equally well at all depths of submergence. The same effect on water grass was noted for all dates of seeding. However, on late-sown plats seepage started growth of barnyard grass before the rice was sown and the plats submerged, and these plats had more grass and poorer stands each year than those not affected by seepage. Scum also is more troublesome with late-sown rice.

EFFECT OF SOWING BROADCAST IN THE WATER

The effect of sowing broadcast was compared with other methods of sowing. In this experiment the plats were submerged on May 16 to the required depths and the rice was then sown broadcast in the water. The effect on water-grass control was the same in this experiment as when the rice was sown broadcast on the soil and the land immediately submerged. However, less seed usually is required to obtain good stands when rice is sown broadcast in the water than when it is sown broadcast and then submerged, and a certain quantity of seed is also saved by protection from birds, but the increased cost of seeding in the water will likely more than offset such saving of seed.

EFFECT OF DRILLING SEED

On these plats the rice was drilled about 1 to 1½ inches deep and immediately submerged to a depth of 6 inches. The water grass was effectively controlled, but poor stands and comparatively low yields of rice were obtained. It was observed on these plats and on other plats with thin stands of rice that redstem (*Ammannia coccinea*), annual sedge (*Cyperus difformis*), and cat-tail (*Typha latifolia*) were often present. When these weeds make much growth they reduce the yields of rice.

EFFECT OF IRRIGATING DRILLED CHECK PLATS IN THE ORDINARY WAY

The check plats were drilled and then when necessary were irrigated and drained at intervals until 30 days after the rice emerged. The plats were then submerged 6 inches. Some water grass and sprangletop were present on these plats in 1922. The plats were foul in 1923 and extremely foul in 1924. The growth of water grass on the check plats was so great in 1923 and 1924 that the yields of rice were materially reduced.

YIELD DATA

Table 6 presents the annual and average acre yields obtained from rice seed sown broadcast on different dates and immediately submerged to different depths during the three years 1922, 1923, and 1924. The average data are shown graphically in Figure 3.

The yields given are the average of two tenth-acre plats in each case, except for the drilled plats sown and submerged on April 25, which are averages of two fifteenth-acre plats, and for the check plats, which are averages of four tenth-acre plats.

In 1922 on fallow land the acre yields were comparatively high for all dates and depths of submergence. In 1923 and 1924 the plats sown broadcast and immediately submerged on April 25 and May 5 produced considerably higher acre yields than were obtained from plats sown broadcast and immediately submerged on May 15 and May 25.

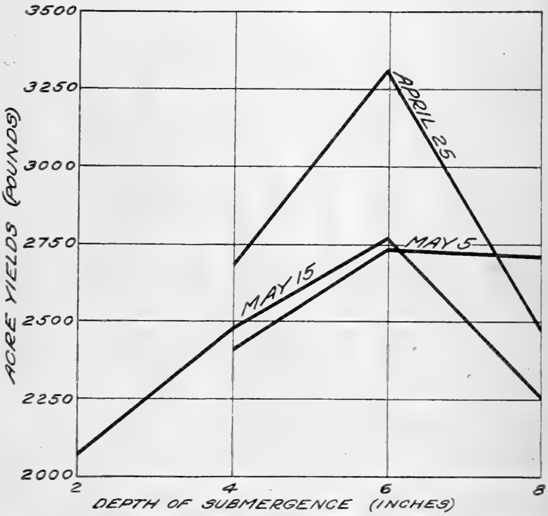

FIG. 3.—Average yields of rice sown on three dates and immediately submerged at four different depths at the Biggs Rice Field Station in 1922, 1923, and 1924

The average acre yields for the plats sown broadcast and immediately submerged 4 inches for all dates of seeding in 1922, 1923, and 1924 were 3,278, 2,132, and 1,735 pounds, respectively. The plats sown broadcast and immediately submerged 6 inches yielded 3,461, 2,425, and 1,947 pounds, respectively; and the plats sown broadcast and immediately submerged 8 inches yielded 3,274, 2,030, and 1,601 pounds, respectively. The average acre yield for 1922, 1923, and 1924 for plats sown broadcast and immediately submerged 4 inches for all dates of seeding was 2,382 pounds; for plats sown broadcast and immediately submerged 6 inches, 2,611 pounds; and for plats sown broadcast and immediately submerged 8 inches, 2,302 pounds. The acre yields of the plats sown broadcast and immediately submerged 6 inches have been higher each year than for the plats submerged 4 and 8 inches; but the difference is not marked and in the light of seasonal variations from the average may not be significant.

TABLE 6.—*Yields of Caloro rice on plats submerged immediately after broadcast seeding in date-of-seeding and depth-of-submergence experiments at the Biggs Rice Field Station in 1922, 1923, and 1924*

Seeding		Submergence		Acre yields (pounds)					
Date	Method	Date	Depth (inches)	1922	1923	1924	Average	Compared with check	
								Gain	Loss
April 25	Broadcast on soil	Apr. 25[1]	4	3,295	2,365	2,395	2,685	874	
Do	do	do.[1]	6	[2] 3,520	[2] 3,265	[2] 3,125	3,303	1,492	
Do	do	do.[1]	8	3,265	2,115	2,020	2,467	656	
May 5	do	May 5	4	2,605	2,530	2,080	2,405	594	
Do	do	do	6	3,290	2,655	2,245	2,730	919	
Do	do	do	8	3,075	2,620	2,430	2,708	897	
May 15	do	May 1	2	2,850	2,090	1,270	2,070	259	
Do	do	do	4	3,695	2,075	1,655	2,475	664	
Do	do	do	6	4,250	2,380	1,675	2,768	957	
Do	do	do	8	3,645	1,925	1,195	2,255	444	
May 16	Broadcast in the water	do	4	3,700	2,190	1,735	2,542	731	
Do	do	do	6	2,805	1,625	1,010	1,813	2	
Do	do	do	8	4,010	2,130	1,310	2,483	672	
May 25	Broadcast on soil	May 25[3]	4	3,515	[4] 1,560	[4] 810	1,962	151	
Do	do	do.[3]	6	2,785	[4] 1,400	[4] 745	1,643		168
Do	do	do.[4]	8	3,110	[4] 1,460	[4] 760	1,777		34
April 25	Drilled	Apr. 25[1]	6	1,740	2,392	1,777	1,970	159	
Do	Drilled (check)	June 15[5]	6	3,25	1,572	610	1,811		

[1] Submerged on Apr. 28, 1922.
[2] Yields increased by an old fill and previous treatment.
[3] Submerged on May 26, 1924.
[4] Affected by seepage.
[5] Submerged on June 11, 1924.

The three-year average acre yield of the plats sown broadcast and immediately submerged 4, 6, and 8 inches on May 15 is higher than that of the plats sown broadcast in 4, 6, and 8 inches of water on May 16. The difference, 220 pounds per acre, may be significant. The highest three-year average acre yield of the plats sown broadcast and immediately submerged on May 15 was obtained from the plats submerged 6 inches; the highest acre yield for the plats sown broadcast in the water was obtained from the plats submerged 4 inches. The cost of sowing in the water is much higher than for sowing broadcast on the soil, and although it is possible to obtain a stand with less seed when the rice is sown in the water this saving in seed would likely be more than offset by the increased cost of seeding.

The yields of plats sown broadcast and plats drilled and submerged 6 inches on April 25 are much higher each year for the plats sown broadcast. When rice seed is drilled and immediately submerged considerable seed rots, and this results in poor stands and usually in low yields.

Rice sown broadcast and immediately submerged 4, 6, or 8 inches, or rice sown in the water for all dates of seeding except for the plats submerged 6 and 8 inches on May 25, gave higher average yields than the check plats. The average increase in yields over the check plats varied from 2 to 1,492 pounds per acre. Slight differences in yield are certainly not significant; larger differences, 400 pounds per acre or more, probably are. Many of the modifications show increases of more than 500 pounds per acre above the control, and the methods of irrigation which result in these increased yields are apparently superior to the method used on the control plats.

Table 7 shows the average agronomic data for Caloro rice grown by the old method of irrigation (check) and by continuous submergence for different dates of seeding during the three years 1922, 1923, and 1924. All plats were submerged about 6 inches. The check plats were drilled on April 25 and the average date of the first irrigation was April 27. They were then drained and again irrigated and drained at intervals until 30 days after the rice had emerged, when the plats were permanently submerged until drained for harvest. The other plats were sown broadcast and immediately submerged. After submergence the water was held continuously at as nearly a uniform depth as possible under field conditions until the land was drained for harvest. The average time required from the date of the first irrigation to emergence of drilled rice was 17 days and for broadcast rice about 21 days. The number of days between the date of first irrigation or submergence and maturity varies with the date of seeding and method of irrigation. Drilled rice irrigated by the old method is slower in reaching maturity than rice sown broadcast and immediately submerged. The time gained by continuous submergence over the old method of irrigation is 5 days for the early-sown rice. The comparison for the later dates is not a true measure of the actual difference, since all dates of broadcast seeding are compared with the early-sown check plats. A check plat sown on each date of seeding would give a more accurate comparison. However, the results show that rice sown broadcast and immediately submerged requires from 5 to 10 days less time to reach maturity than rice irrigated in the old way. This gain in maturity of from 5 to 10 days by continuous submergence is a very important point in favor of this method of irrigation and in certain years may mean the difference between success and failure. It also indicates the possibility of growing later-maturing varieties in normal years without unduly delaying harvest, and this would probably mean larger acre yields.

TABLE 7.—*Average agronomic data for Caloro rice grown by the old method of irrigation and by continuous submergence immediately after broadcast seeding at the Biggs Rice Field Station in 1922, 1923, and 1924.*

Variety	Date of—							Days from first irrigation to maturity	Days gained in comparison with check
	Seeding	Submergence	Emergence	First heading	Full heading	First ripe	Ripening		
Caloro (check)	Apr. 25[1]	June 15	May 14	Aug. 22	Sept. 1	Sept. 13	Oct. 3	159	------
Caloro	do	Apr. 26	May 18	Aug. 15	Aug. 26	Sept. 9	Sept. 27	154	5
Do	May 5	May 5	May 26	Aug. 19	Aug. 29	Sept. 11	Sept. 30	148	11
Do	May 15	May 15	June 4	Aug. 24	Sept. 3	Sept. 15	Oct. 4	142	17
Do	May 25	May 25	June 15	Aug. 27	Sept. 6	Sept. 19	Oct. 9	137	22

[1] The average date of first irrigation was April 27

COMPARISON OF AIR AND WATER TEMPERATURES

Rice is commonly sown in California between April 15 and May 15. At this time the temperatures of the air, water, and soil usually are too low for maximum germination. During the growing season of 1923 and 1924 a soil thermograph was used to get temperature records on a plat sown broadcast and submerged 6 inches on April 25.

The soil thermograph "torpedo" was placed horizontally on the surface of the soil beneath the 6 inches of water. The maximum and minimum air temperatures were taken daily under shade, but with a free circulation of air. Records were taken from May to September, inclusive.

The average maximum temperatures during 1923 and 1924 for the five-month period from May to September, inclusive, were, respectively, 87.8° and 90.9° F. for the air and 79.6° and 78.5° F. for the water. The average minimum temperatures for the same five-month period were, respectively, 56.4° and 56.3° F. for the air and 60.6° and 63.4° F. for the water. For the two-year period the average maximum air temperature was 10 degrees higher than the average maximum water temperature. But the average minimum air temperature was about 6 degrees lower than the average minimum water temperature.

The average maximum air and water temperatures in 1923 and 1924 for the months of May and June, during which time the rice was germinating and before it was large enough to shade the water effectively, were, respectively, as follows: For May, air 80.1° and 86.4°, water 82.7 and 84.7° F.; for June, air 83.5° and 90.0°, water 85.0° and 87.9° F. The average minimum temperatures for the same months were, respectively, as follows: For May, air 50.9° and 53.1°, water 53.7° and 61.0° F.; for June, air 54.0° and 57.4°, water 58.6° and 65.9° F. For the two-year period the average maximum air and water temperatures for May and June were about equal, but the average minimum temperature for the same months was about 6 degrees higher for the water than for the air.

Each year during July, August, and September the water was almost completely shaded by the rice crop, and the average maximum air temperature for each month was higher than the average maximum water temperature. However, the average minimum water temperature for each month has ranged from 1.5 to 7.7 degrees higher than the average minimum air temperature.

The temperature readings in 1923 and 1924 indicate that water to a depth of 6 inches maintains a higher and more uniform temperature than the air during the period of germination and early growth. During July, August, and September, when the water is shaded by the rice crop, the mean air temperatures are higher than the mean water temperatures. This indicates that, in so far as temperature alone is concerned, conditions are more favorable for germination under 6 inches of water than they are in the atmosphere or than they are presumably at the surface of the soil.

EXPERIMENTS ON SUBMERGENCE IMMEDIATELY AFTER THE RICE HAS EMERGED

BROADCASTING AND DRILLING SEED COMPARED

Experiments to compare broadcasting and drilling were conducted during 1922, 1923, and 1924 on land that had been sown to rice and fallowed in the cultural experiments in alternate years from 1914 to 1921. In 1921 the land was fallowed. The 1922 crop was the fifth rice crop on this land in 9 years, the 1923 crop was the sixth rice crop in 10 years, and the 1924 crop was the seventh rice crop in 11 years. In the spring of 1922 the fallow land was double disked and harrowed. For the 1923 and 1924 crops the land was spring plowed, double disked, harrowed, and dragged. Each year these tillage operations provided a good seed bed.

The annual yields of all except the check plats represent the average yields of two tenth-acre plats. The annual yields of the broadcast checks are for two plats irrigated by the old method. The annual yields of the drilled checks are the average of four plats in all cases except the yield recorded for the May 5 seeding in 1923, which is for only two plats.

In these experiments alternate plats, usually inclosed by the same levees, were sown broadcast and drilled, respectively. Each year the rice was irrigated and the plats drained three times before the plats finally were submerged to the required depths. On the date of submergence the rice and water grass varied in height from 1 to 2 inches.

The plats submerged 2 and 4 inches were very foul with water grass and sprangletop each year, but were worse in 1923 and 1924 than in 1922. On plats submerged 6 and 8 inches the water grass was controlled to a marked extent, but at these depths a good deal of rice also was suffocated each season. Some barnyard grass and sprangletop were present on all plats each year, but these grasses were much more abundant on the control plats and those submerged 2 and 4 inches than on plats submerged 6 and 8 inches.

Table 8 shows the annual and average acre yields from plats sown both broadcast and drilled on two different dates and submerged at various depths after the rice emerged in 1922, 1923, and 1924, inclusive. Each year better stands and higher yields were obtained from plats sown on April 25 than from those sown on May 5. In 1922 and 1923 the yields from the plats sown on April 25 were so much higher than from those sown on May 5 that the latter date of seeding was omitted in 1924.

The average acre yields for both dates of seeding show that at each depth of submergence the average yields of the drilled plats were higher than those of the broadcast plats except for the plats sown on May 5 and submerged 8 inches. The increased yields from the drilled plats, however, in most cases are small and therefore probably not significant.

The three-year average acre yield of the plats sown on April 25 and submerged at various depths after the rice emerged shows an increase above the check plats ranging from 73 to 283 pounds. The highest average acre yield, 2,163 pounds, was obtained from drilled plats submerged 2 inches after the rice emerged. But the difference in yield of plats submerged 2, 4, 6, and 8 inches is not sufficient to indicate with any certainty that in this case one depth of submergence is distinctly superior to another. This method of irrigation, based on the results presented in Table 8 for the April 25 date of seeding, is not markedly, if at all, superior to the old method of irrigation. The submergence of drilled or broadcast rice soon after emergence is decidedly inferior to continuous submergence immediately after the rice is sown broadcast (Table 6), both in regard to water-grass control and to rice yields.

TABLE 8.—*Yields of Caloro rice obtained on plats sown on two dates, both broadcast and drilled, and submerged at various depths after the rice emerged at the Biggs Rice Field Station in 1922, 1923, and 1924.*

Date and method of seeding	Submergence		Acre yields (pounds)					
							Compared with check	
	Date	Depth (inches)	1922	1923	1924	Average[1]	Gain	Loss
April 25:								
Broadcast on soil	May 29[2]	2	2,280	1,830	1,390	1,833	131	
Drilled	do.[2]	2	2,690	2,110	1,690	2,163	269	
Broadcast on soil	do.[2]	4	2,580	2,240	1,135	1,985	283	
Drilled	do.[2]	4	2,450	1,985	1,465	1,967	73	
Broadcast on soil	do.[2]	6	2,060	2,095	1,510	1,888	186	
Drilled	do.[2]	6	2,480	1,815	1,660	1,985	91	
Broadcast on soil	do.[2]	8	2,300	1,520	1,530	1,783	81	
Drilled	do.[2]	8	2,270	2,145	1,870	2,095	201	
Broadcast on soil[3]	June 15[4]	6	2,590	1,645	870	1,702		
Drilled[3]	do.[4]	6	2,450	2,004	1,227	1,894		
May 5:								
Broadcast on soil	June 8[5]	4	2,050	1,220		1,635	425	
Drilled	do.[5]	4	2,060	1,675		1,867	177	
Broadcast on soil	do.[5]	6	1,995	1,210		1,602	392	
Drilled	do.[5]	6	2,085	1,320		1,702	12	
Broadcast on soil	do.[5]	8	1,825	905		1,365	155	
Drilled	do.[5]	8	1,735	825		1,280		410
Broadcast on soil[3]	June 25	6		1,210		1,210		
Drilled[3]	do	6	1,875	1,505		1,690		

[1] The two-year average for the May 5 date of seeding.
[2] Submerged on May 24, 1923, and on May 22, 1924.
[3] Used as checks on the two methods of seeding, respectively, for April 25 and May 5.
[4] Submerged on June 12, 1924
[5] Submerged on June 4, 1923.

The young rice plant or seedling apparently is unable to adjust itself to the sudden change from a dry or moist soil to a submerged life. Many young plants are suffocated when submerged in deep water (6 and 8 inches), and those which emerge to the water surface are slow in regaining, if they ever fully regain, their normal viability. However, when the rice seed germinates under water and the seedlings emerge through the water such plants appear to be more vigorous than plants grown by the old method of irrigation.

SPRING PLOWING AND DISKING OF STUBBLE LAND COMPARED

Experiments comparing spring plowing and disking were conducted on land which had been alternately cropped to rice and fallowed in the cultural experiments from 1914 to 1921. The land produced a rice crop in 1921. The 1922 crop was the sixth rice crop on this land in 9 years, the 1923 crop was the seventh rice crop in 10 years, and the 1924 crop was the eighth rice crop in 11 years.

In the spring one series of plats was double disked and harrowed each year during the three years 1922, 1923, and 1924. A second series of plats at the same time was spring plowed, double disked, and dragged. These tillage operations prepared a good seed bed on the spring-plowed land, but a poor, hard, grassy seed bed on the disked stubble land.

In these experiments alternate plats, usually inclosed within the same levees, were sown broadcast and drilled. Each year the rice was irrigated and drained three times before the plats were submerged to the required depths. On the date of submergence the rice and water grass varied in height from 1 to 2 inches.

Although the plats submerged 6 and 8 inches grew much less water grass than plats submerged 2 and 4 inches, the stands of rice on the more deeply submerged plats were too thin to produce good yields. The stands on the deep-water plats also were reduced in 1922 by injury from leaf miners and by the growth of spike rush.

Spike rush (*Eleocharis palustris*), locally known as wiregrass, cattail (*Typha latifolia*), slender aster (*Aster exilis*), annual sedge (*Cyperus difformis*), and canary grass (Phalaris) were very thick each year on the disked stubble land. The spike rush, slender aster, and cattail were especially bad on the disked stubble land in 1923 and 1924. These weeds are controlled to a large extent by good spring plowing followed by drying weather.

The annual and average acre yields for the method-of-seeding experiments on spring-plowed and on disked stubble land submerged at various depths after the rice emerged during the years 1922, 1923, and 1924 are given in Table 9.

Each of the four check plats was a single tenth-acre plat each year and irrigated in the old way. The yields of plats submerged 2 inches are for single fifteenth-acre plats each year. The circled figures in Table 9 represent the number of tenth-acre plats averaged where more than one was grown.

TABLE 9.—*Yields of rice obtained on spring-plowed and on disked stubble land, both drilled and sown broadcast and submerged at various depths after the rice emerged, at the Biggs Rice Field Station in 1922, 1923, and 1924*

[The circled figures represent the number of tenth-acre plats averaged where more than one was grown]

Seed-bed preparation	Method of seeding	Submergence		Acre yields (pounds)					
		Date	Depth (inches)	1922	1923	1924	Average	Compared with check: Gain	Compared with check: Loss
Spring plowed	Drilled	May 30	2	3,510	2,115	2,310	2,645	325	------
Double disked	do	do	2	2,430	1,395	720	1,515	------	380
Spring plowed	Broadcast	do	4	② 2,585	② 2,235	1,670	2,163	343	------
Double disked	do	do	4	② 2,180	② 1,335	890	1,468	133	------
Spring plowed	Drilled	do	4	② 2,460	③ 2,605	1,820	2,295	------	25
Double disked	do	do	4	② 2,455	② 1,510	1,320	1,762	------	133
Spring plowed	Broadcast	do	6	③ 2,317	③ 2,037	② 1,870	2,075	255	------
Double disked	do	do	6	③ 1,803	③ 1,177	② 770	1,250	------	85
Spring plowed	Drilled	do	6	④ 2,248	④ 2,042	② 2,140	2,143	------	177
Double disked	do	do	6	④ 2,048	③ 1,383	② 975	1,469	------	426
Spring plowed	Broadcast	do	8	③ 1,360	③ 1,640	② 1,610	1,537	------	283
Double disked	do	do	8	③ 1,037	② 980	② 840	952	------	383
Spring plowed	Drilled	do	8	② 1,540	② 1,950	② 1,985	1,825	------	495
Double disked	do	do	8	② 1,405	② 710	② 855	990	------	905
Spring plowed	Broadcast[1]	June 16	6	1,760	1,880	----------	1,820	------	------
Double disked	do.[1]	do	6	1,780	890	----------	1,335	------	------
Spring plowed	Drilled[1]	do	6	2,220	2,420	----------	2,320	------	------
Double disked	do.[1]	do	6	2,590	1,200	----------	1,895	------	------

[1] Used as checks for the two methods of preparation and of seeding, respectively.

In these experiments, as in those just described, there was a small increase in yield for drilled plats over broadcast plats at each depth of submergence. However, the differences are small in most instances. In irrigating and draining to germinate the seed it was difficult, when broadcast and drilled plats were inclosed within the same levees, to handle the water in such a manner that maximum stands would be obtained on both plats. Drilled rice does not germinate well if excessive moisture is present, while broadcast rice needs a very wet soil to insure a high percentage of germination and good stands. The stands each year were better for the drilled plats in these and the preceding experiments, probably because moisture conditions were better suited for drilled than for broadcast rice during the period of germination.

The average acre yields for plats sown broadcast and drilled on spring-plowed and on disked stubble land submerged 4, 6, and 8 inches after the rice emerged, decreased in each case with increased depths of submergence. The three-year average acre yield of the drilled plats for all depths of submergence on spring-plowed land was 2,227 pounds, of the broadcast plats on spring-plowed land 1,925 pounds, of the drilled plats on disked stubble land 1,434 pounds, and of the broadcast plats on disked stubble land 1,223 pounds. The three-year average acre yield for all plats, including drilled and broadcast, on spring-plowed land submerged 2, 4, 6, and 8 inches was 2,098 pounds and on disked stubble land 1,344 pounds, or an average difference of 754 pounds per acre in favor of the spring-plowed plats. This increase in yield (754 pounds per acre) is significant and shows the advantage of plowing for rice. The chief benefits of plowing are probably due to the control of such weeds as spike rush, cat-tail, slender aster, canary grass, and perennial sedge, which were largely responsible for the low annual yields on the disked stubble land.

The method of irrigation used in this series of experiments, as previously stated, is inferior to continuous submergence immediately after broadcasting, both in the control of weeds and in rice yields.

EXPERIMENTS ON RATE OF SEEDING AND METHOD OF IRRIGATION

Rate-of-seeding and method-of-irrigation experiments were conducted on land previously used in the irrigation experiments. The land was fallowed in 1921. The 1922 crop was the sixth rice crop in 9 years, the 1923 crop was the seventh rice crop in 10 years, and the 1924 crop was the eighth rice crop on this land in 11 years. In the spring of 1922 the land was twice double disked, harrowed, and dragged. For the 1923 and the 1924 crops the land was spring plowed, double disked, harrowed, and dragged. These tillage operations resulted in a good seed bed each year.

On series 1 the rice was sown broadcast and the plats were immediately submerged about 6 inches. On series 2 the rice was drilled and irrigated and drained twice before emergence. It was then submerged about 6 inches. On series 3 the rice was drilled and irrigated and drained at 10-day intervals until 30 days after emergence. It was then submerged about 6 inches.

The plats on which the rice was sown broadcast and immediately submerged (series 1) were practically free of water grass and sprangletop each year. There was some annual sedge on certain of these plats each year, due to thin stands of rice. Plats on which the rice was drilled and irrigated and drained twice before submergence (series 2) had a good deal of water grass and sprangletop present each year. The plats irrigated in the old way (series 3) were foul in 1922, very foul in 1923, and extremely foul in 1924.

Table 10 presents the annual and average acre yields for the rate-of-seeding and method-of-irrigation experiments during the three years, 1922, 1923, and 1924.

The annual yields reported in Table 10 are for single fifth-acre plats each year. The plat sown at the rate of 190 pounds in series 1 is more favorably located with reference to drainage than the other plats, and this may have influenced yields.

In 1922 on fallow land the average acre yield, including all rates of seeding, was about the same for all series. In 1923 the average acre yield, including all rates of seeding, was higher for series 1 than for series 2 and considerably higher than for series 3. In 1924 the average acre yield, including all rates of seeding, was 2,502 pounds for series 1, 947 pounds for series 2, and 566 pounds for series 3. It is interesting to note that the average acre yield, including all rates of seeding for series 1, was higher in 1924 than in either 1922 or 1923, while the average acre yield, including all rates of seeding for series 2, was 16 per cent lower in 1923 and 60 per cent lower in 1924 than in 1922. For series 3 the average acre yield, including all rates of seeding, was 30 per cent lower in 1923 and 75 per cent lower in 1924 than in 1922. The results show that during the period of cropping covered by the experiment yields were maintained at about 2,200 to 2,500 pounds when water grass and other weeds were reasonably well controlled. Where weeds were not controlled there was a rapid decrease in yield, the decrease being proportional to the increased weed growth.

TABLE 10.—*Yields of Caloro rice obtained in the rate-of-seeding and method-of-irrigation experiments at the Biggs Rice Field Station in 1922, 1923, and 1924*

Rate of seeding	Acre yields (pounds)											
	Series 1			Series 2			Series 3			Three-year averages		
	Sown May 5, submerged May 9, 1922	Sown May 10, submerged May 11, 1923	Sown May 8, submerged May 10, 1924	Sown April 26, submerged May 23, 1922	Sown April 30, submerged May 25, 1923	Sown April 26, submerged May 20, 1924	Sown April 26, submerged June 18, 1922	Sown April 30, submerged June 14, 1923	Sown April 26, submerged June 12, 1924	Series 1	Series 2	Series 3
115 pounds	1,840	2,325	2,580	[1] 1,350	1,830	935	1,690	1,355	460	2,248	1,372	1,168
130 pounds	1,860	2,285	2,710	2,650	2,300	1,065	2,925	1,805	700	2,285	2,005	1,810
150 pounds	2,980	2,075	2,335	2,735	2,140	1,060	2,660	1,730	630	2,463	1,978	1,673
175 pounds	[2] 1,815	[2] 1,800	[2] 1,740	[2] 2,380	[2] 1,690	[2] 650	2,295	1,530	530	1,785	1,573	1,452
190 pounds	3,125	2,555	3,145	2,605	1,845	1,025	1,720	1,435	510	2,942	1,825	1,222
Average	2,324	2,208	2,502	2,344	1,961	947	2,258	1,571	566	------	------	------

[1] Yield reduced by leaf miners.

[2] Yields probably reduced by nonuniform land.

In general, rice growers agree that it requires more seed to obtain good stands when sown broadcast than when drilled. The three-year average acre yields in Table 10 show that the plats sown broadcast in series 1 gave the highest yields from sowing at the rate of 150 and 190 pounds per acre, whereas the drilled plats in series 2 and 3 gave the highest yields from the 130 and 150 pound rates. On the other hand, each rate of seeding in series 1 produced a higher average acre yield than the corresponding rate in series 2, and likewise each rate of seeding in series 2 outyielded the corresponding rates in series 3. This emphasizes the fact that the method of irrigation, because of its effect on grass control and consequent rice yields, is the most important factor for consideration.

EXPERIMENTS ON SEED-BED PREPARATION

The land on which seed-bed experiments were conducted had grown six rice crops in nine years and was very foul. It produced a crop in 1921 by continuous submergence. The land was spring plowed, double disked, and dragged in the spring in 1922 and 1923, except two plats which received no seed-bed preparation in 1922. In 1924 the experiments and yields here reported were obtained on the first eight plats of series 300, 400, 500, and 600.

The yields for the plats submerged 4 inches in 1922 and 1923 were obtained from single half-acre plats; those for the plats sown broadcast and submerged 6 inches were from duplicate half-acre plats; those for plats sown broadcast in 6 inches of water were from single third-acre plats; those for plats sown broadcast and submerged 8 inches were from duplicate and triplicate half-acre plats, respectively; those plats sown broadcast at the rate of 200 pounds per acre were from triplicate third-acre plats; and those for plats sown on unprepared land were from single fourth-acre plats. The yields reported for 1924 were obtained on tenth-acre plats, and the circled figures given with the data in Table 11 indicate the number of plats averaged where more than one was grown. The rice was either sown broadcast and immediately submerged to the required depths, or the land was submerged and the rice then sown broadcast in the water.

TABLE 11.—*Yields of Caloro rice obtained by broadcast seeding on well-prepared, poorly prepared, and unprepared seed beds with different depths of submergence at the Biggs Rice Field Station in 1922, 1923, and 1924*

[The circled figures indicate the number of plats averaged where more than one was grown]

Seed-bed preparation	Seeding		Date of submergence	Depth of submergence (inches)	Acre yields (pounds)			
	Date	Method			1922	1923	1924	Average
Good	May 9	Broadcast	May 11	4	3,492	2,148	(6) 2,583	2,741
Do	do	do	do	6	3,553	1.959	(12) 2,440	2.651
Do	May 15[1]	Broadcast in water	do	6	3,144	1,941	1,625	2,237
Do	May 9[2]	Broadcast	do	8	3,589	2,661	(6) 1,973	2,741
Do	do.[2]	do	do	6	2,590	2,030		2,310
Poor	do	do	do	4			(2) 1,425	
None or poor	do	do	do	6	2,768		(4) 1,257	2,012
Poor	do	do	do	8			(2) 645	

[1] Submerged on May 14, 1923. [2] Sown at the rate of 200 pounds per acre.

WEED CONTROL

Effect of good preparation.—On well-prepared seed beds there was very little water grass on plats continuously submerged 4, 6, and 8 inches, except for the white, or "Japanese," barnyard grass, which was present to a considerable extent on all plats in 1921 and 1922 and was sufficiently thick in 1923 to reduce rice yields materially.

The results indicate that white water grass can not be controlled by continuous submergence at these depths. Observations along "barrow pits" at the base of levees and in dead furrows indicate that water ranging from 10 to 15 inches deep does aid materially in the control of white water grass. At such depths, however, it is difficult to get good stands of rice, and it is impracticable also to hold the water so deep. It therefore appears that white water grass when thin should be hand pulled to prevent spreading.

Effect of no preparation.—The plats sown in 1922 on stubble land without seed-bed preparation and those sown in 1924 on double-disked stubble land were very foul with spike rush, cat-tail, slender aster, and canary grass. Barnyard grass also was much thicker than on plats which were spring plowed. Some water grass usually germinates in the spring before the rice land is prepared for seeding, and such plants must be killed by cultivation, as it is practically impossible to control or suffocate them with water 6 to 8 inches deep.

Control of cat-tail.—Seeding at the rate of 200 pounds per acre on land badly fouled with cat-tail did not check its growth. However, observations during past years indicate that on clean land good stands of rice are very helpful in preventing cat-tail from becoming established. Cat-tail usually first appears in a field where the stands of rice are poor; that is, along the levees and on low land where it is difficult to obtain good stands of rice.

YIELD DATA

Table 11 presents the annual and average acre yields from the seed-bed preparation experiments for the three-year period. On a well-prepared seed bed there is little difference in the average acre yields of plats sown broadcast and immediately submerged 4, 6, or 8 inches. The average yield of the plats sown broadcast in 6 inches of water was considerably less than for the plat sown broadcast and immediately submerged 6 inches. The yields on unprepared and poorly prepared seed beds, while fragmentary, indicate that there is more effect on yield from depth of submergence. All of the data taken together show conclusively that good seed-bed preparation is a desirable practice. On poorly prepared seed beds acre yields are materially reduced by competition with weeds, such as spike rush, cat-tail, slender aster, and water grass.

RATE-OF-SEEDING EXPERIMENTS

EFFECT OF VARIETY

Those who are familiar with the growing of cereal crops know that the maximum yield of a given variety is not likely to be obtained from the same rate of seeding every year. However, in a period of years each variety probably will produce its maximum average yield at some constant rate of seeding. It is not possible to conduct a rate-of-seeding experiment for each variety, because of the large number of varieties. Recommendations as to the best rate of seeding are therefore usually based on the results of rate-of-seeding experiments with one or two of the leading commercial varieties grown in a given area.

The rate of seeding rice is influenced by many factors, some of the most important of which are variety, age of seed, quality of seed, date of seeding (temperature), depth of seeding, method of seeding, condition of the seed bed, method of irrigation, and kind of land, whether new or old, rich or poor.

In 1921 a rate-of-seeding experiment was started, including three varieties of rice—Selection No. 175, Caloro, and Wataribune (C. I. No. 1561). The land used for this experiment was fallowed in 1920. The 1921 crop was therefore grown on fallow land, and the 1922 and 1923 crops were grown on spring-plowed stubble land.

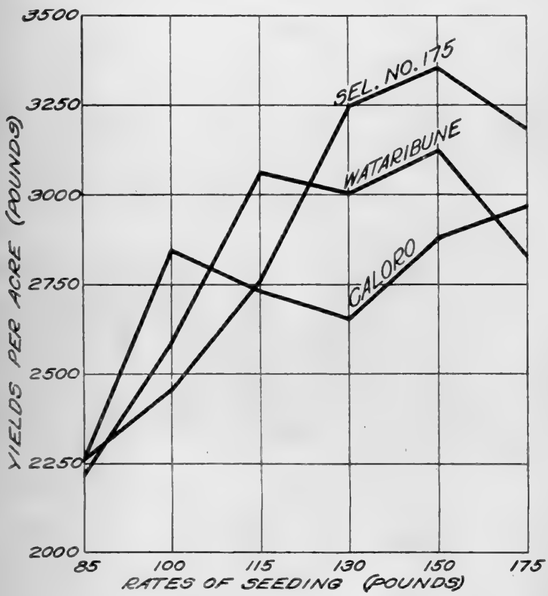

FIG. 4.—Average yields of three rice varieties grown in rate-of-seeding experiments at the Biggs Rice Field Station in 1921, 1922, and 1923

Each varietal rate-of-seeding experiment was located on the same plat each year. A reasonably good seed bed was prepared before seeding. The rates of seeding for each variety ranged from 85 to 175 pounds per acre. The rice on all plats was sown with a drill on the same date each year.

After seeding, all plats were irrigated and drained at frequent intervals until 30 days after the rice emerged. The land then was submerged about 6 inches and the water held at this depth until the land was drained for harvest. Each year the water grass which appeared was hand pulled before it reached maturity.

YIELD DATA

Table 12 presents the annual and average acre yields for the rate-of-seeding experiment with Selection No. 175, Caloro, and Wataribune in 1921, 1922, and 1923. The average data are shown graphically in Figure 4. For Selection No. 175 the average acre yield increased for each increased rate of seeding from 85 to 150 pounds per acre. The average acre yields for Wataribune show consistent increases with increased rates of seeding from 85 to 150 pounds per acre except for the 130-pound rate. For Caloro the average yield did not show consistent increases for increased rates of seeding. The highest average yields were obtained from the 175-pound and 150-pound rates, although that for the 100-pound rate was nearly as good. These results indicate that on old land rice probably should be sown at the rate of about 150 pounds per acre.

The three-year average acre yield of the three varieties at all rates of seeding was 2,876 pounds for Selection No. 175, 2,718 pounds for Caloro, and 2,801 pounds for Wataribune.

TABLE 12.—*Yields from tenth-acre plats of Selection No. 175, Caloro, and Wataribune rices grown in rate-of-seeding experiments at the Biggs Rice Field Station in 1921, 1922, and 1923*

Rate of seeding	Acre yields (pounds)											
	Selection No. 175			Caloro			Wataribune			Three-year average		
	1921	1922	1923	1921	1922	1923	1921	1922	1923	Selection No. 175	Caloro	Wataribune
85 pounds	1,880	2,450	2,450	2,380	2,690	1,650	2,150	2,340	2,140	2,260	2,240	2,210
100 pounds	2,660	2,560	2,140	2,630	3,260	2,640	2,800	2,650	2,310	2,453	2,843	2,587
115 pounds	2,710	2,920	2,650	2,460	3,170	2,550	3,210	3,170	2,790	2,760	2,727	3,057
130 pounds	2,740	3,630	3,350	2,510	2,980	2,470	3,160	3,160	2,680	3,240	2,653	3,000
150 pounds	3,030	3,510	3,540	2,860	3,180	2,600	3,640	3,110	2,620	3,360	2,880	3,123
175 pounds	2,450	3,820	3,280	3,080	2,900	2,917	3,290	2,770	2,420	3,183	2,966	2,827
Average	2,578	3,148	2,902	2,653	3,030	2,471	3,042	2,867	2,493	2,876	2,718	2,801

EFFECT OF CONTINUOUS CROPPING ON RICE YIELDS

In the older rice-producing countries of the world rice is reported to be grown on the same land year after year. If this is a common practice there is little doubt that every available means is utilized to maintain and if possible increase the fertility of the soil. The use of manure, green manures, compact materials, sediment from the beds of streams, and commercial fertilizers when practicable is reported to be common on such lands.

In California three or four crops of rice are all that usually have been profitably grown in succession on the same land. This is due largely to the fact that weeds, especially water grass, increase so rapidly that rice yields are seriously reduced thereby and not because the rice has robbed the soil of its fertility.

Every agricultural section has its weed problems, and the solution is usually diversification and rotation of crops. Maximum yields with all cereal crops are usually obtained in rotation systems and not by continous cropping. The yields obtained from rice grown on the same land 11 of the 12 years from 1913 to 1924, inclusive, are presented in Table 13 and are shown graphically in Figure 5. The yield in 1913 was the average from 10 tenth-acre plats. Yields in 1914, 1915, and 1916 were from 12 tenth-acre plats, and those from 1917 to 1924, inclusive, were from 5 tenth-acre plats.

The soil on which these yields were obtained is Stockton clay adobe. From 1913 to 1920, inclusive, the land was fall plowed (except in 1918), well prepared in the spring, and kept free from water grass and cat-tail. For the 1918, 1922, and 1923 crops the land was spring plowed, and for the 1924 crop the land was winter plowed. In each of these years a reasonably good seed bed was prepared after plowing. From 1913 to 1920, inclusive, the rice was grown by the old method of irrigation, all rice was sown with a drill, and water grass and cat-tail were hand pulled. In 1922, 1923, and 1924 the five plats averaged for the yearly yield were treated as follows: One plat was drilled on April 25 and irrigated in the old way; a second plat was sown broadcast on April 25 and immediately submerged 8 inches; a third plat was sown broadcast on May 15 and immediately submerged 4 inches; a fourth plat was sown broadcast in 6 inches of water on May 16; and a fifth plat was sown broadcast and immediately submerged on May 25. The average acre yields of these five plats are lower than they should be each year, because both good and poor methods of production are involved, and only the best method should be considered in such an experiment.

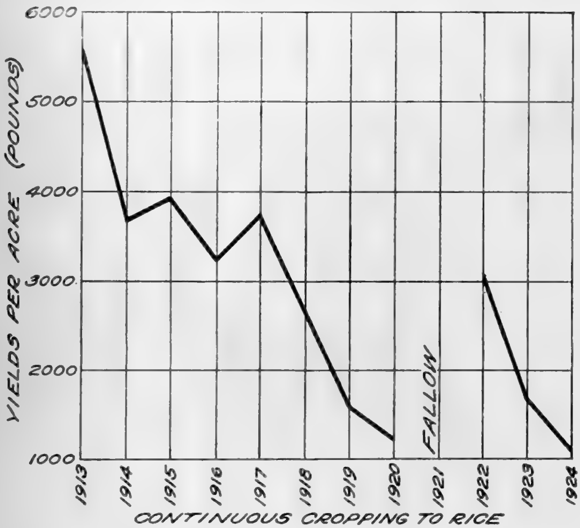

FIG. 5.—Annual yields of rice grown continuously at the Biggs Rice Field Station on the same land from 1913 to 1924, with one intervening year of fallow in 1921

Land on which rice has not been grown before usually produces about 30 per cent more per acre than second-year or third-year land. The annual yields presented in Table 13 do not show a gradual decline with continued cropping, but they show erratic changes probably due to favorable or unfavorable weather conditions in different years. The yield in 1914 on second-year land was less than that for 1915 on third-year land. Likewise, the yield for 1916 on fourth-year land was less than that for 1917 on fifth-year land, and the yield in 1917 was just about the same as that for 1914. Such fluctuations in yield from year to year are to be expected, and they emphasize the important effect of seasonal conditions as well as soil upon crop yields.

TABLE 13.—*Yields of rice grown continuously on the same land for 11 years in 12 at the Biggs Rice Field Station from 1913 to 1924, inclusive*

Variety	Year	Acre yields (pounds)	Crop No.	Remarks
Wataribune	1913	5,677	1	Grown on new land.
Do	1914	3,692	2	Land fall plowed.
Do	1915	3,914	3	Do.
Do	1916	3,231	4	Do.
Do	1917	3,704	5	Do.
Do	1918	2,628	6	Land spring plowed.
Do	1919	1,596	7	Land fall plowed.
Do	1920	1,208	8	Yield from spring-threshed plats.
No crop	1921	----------	Fallow.	
Caloro	1922	3,092	9	Yield on fallow land.
Do	1923	1,672	10	Land spring plowed.
Do	1924	1,094	11	Land winter plowed.
Average:				
11 years, 1913 to 1924, with 1921 omitted	--------	2,864	----------	
12 years, 1913 to 1924, all inclusive	--------	2,626	----------	

Allowing to seasonal fluctuation its full importance in affecting yield, there is yet apparent a distinct decline in acre production between the beginning of the experiment in 1913 and the present in 1924. During the first six years of continuous cropping to rice each year the yields were profitable. In the second 6-year period the only profitable crop was that of 1922, and this was grown on fallow land. The yields in 1919 and in 1920 were not profitable. The threshed yield of 1920 was decreased by winter exposure; but if the yield obtained is increased by one-third it would still be only 1,600 pounds, which is below the limit of profit for that year. The data indicate that rice can not be profitably grown continuously on the same land by the old method of irrigation for more than six years in succession, even though weeds are kept under control. Data on methods of irrigation, which are given elsewhere in this bulletin, indicate that it may be possible to crop continuously for a longer period where irrigation is by continuous submergence. These data cover a period of only three years, however, and are therefore not conclusive.

The 11-year average yield from 1913 to 1924, with 1921 omitted, was 2,864 pounds, and for the 12-year period from 1913 to 1924, all inclusive, 2,626 pounds per acre. These are profitable average crops for the entire period, but the high average yield in each case is due to the high acre yields during the first six years of continuous cropping.

VARIETAL EXPERIMENTS

One of the principal lines of work at the station has been the testing of many varieties of rice from various sources in the hope of finding some that are superior in yield and milling quality to those now being grown commercially in California.

CLASSES OF RICE

The varieties of rice commercially grown in the United States are classed agronomically as long grain, medium grain, and short grain. By the Bureau of Agricultural Economics of the United States Department of Agriculture these rices are classed as long grain, short grain, and round grain, respectively. The short-grain rices have small stalks, narrow leaves, and short, round kernels. The medium-grain rices have rather coarse stalks, comparatively wide leaves, and kernels of medium length. The long-grain rices have large stalks, wide leaves, and long kernels. The short-grain and medium-grain rices usually stool more heavily than the long-grain varieties.

Only a small acreage in Louisiana, Texas, and Arkansas is annually devoted to the short-grain rices, of which Wataribune is probably the leading variety. In California about 99 per cent of the rice crop consists of short-grain rices, of which Caloro, Early Wataribune, Colusa, and Onsen are the leading varieties.

VARIETIES GROWN ON TENTH-ACRE PLATS

During the six years from 1919 to 1924, inclusive, 20 varieties and selections of short-grain rice, 1 medium-grain variety, and 3 long-grain varieties were grown in the field plats at the station.

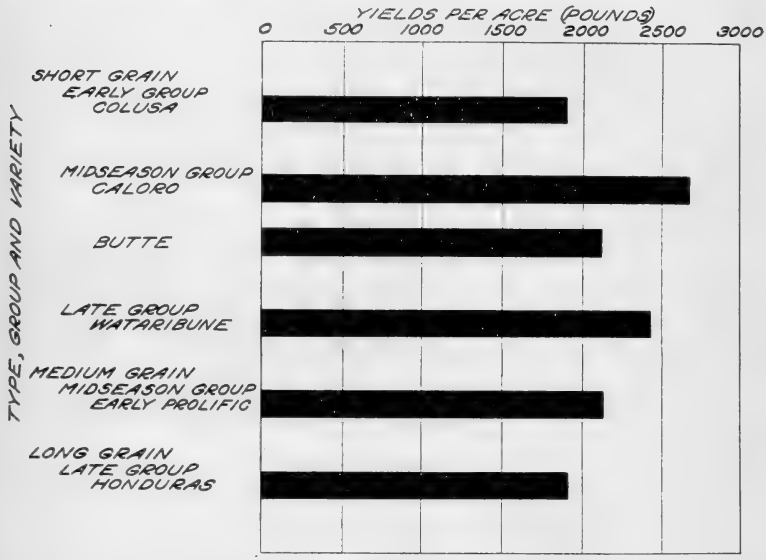

Fig. 6.—Average yields of representative varieties of the three standard types of rice and of different groups of these types grown at the Biggs Rice Field Station during the 6-year period from 1919 to 1924, inclusive

In 1919 the varietal experiment was conducted on fallow land that had produced two crops of rice, in 1920 and 1921 on fallow land that had produced three crops of rice, in 1922 and 1923 on fallow land that had produced four crops of rice, and in 1924 on fallow land that had produced five crops of rice. The seed bed and stands were good each year.

Table 14 gives the yields of the 24 varieties and strains during this period. In the table the short-grain rices and selections are grouped into early, mid-season, and late-maturing varieties. The medium-grained varieties are of the mid-season group, and the long-grain rices are mid-season and late-maturing varieties. The average yields of representative varieties of the different types and groups are shown graphically in Figure 6.

During the six-year period from 1919 to 1924, inclusive, the short-grain mid-season group represented by Selections Nos. 1561–3 and 1561–2 produced higher average acre yields than the short-grain late group represented by Selections Nos. 115 and 114. The long-grain mid-season variety, Selection No. 113, produced a higher average acre yield than either the mid-season medium-grain variety Early Prolific, the long-grain late variety Honduras, or the early short-grain variety Colusa.

TABLE 14.—*Yields of 24 varieties and selections of rice grown at the Biggs Rice Field Station during the six-year period from 1919 to 1924, inclusive*

Type, group, and variety	C. I. No.	Acre yields (pounds)									
		1919	1920	1921	1922	1923	1924	Averages			
								1919 to 1921	1922 to 1924	1920 to 1924	1919 to 1924
SHORT GRAIN											
Early group:											
Colusa	1600	1,500	1,750	1,730	2,000	1,930	2,442	1,660	2,124	1,970	1,892
Onsen	------	------	------	------	1,790	2,170	2,343	------	2,101	------	------
Mid-season group:											
Wataribune Selection	1561–3	3,960	2,640	3,130	3,150	2,273	2,673	3,243	2,699	2,773	2,971
Do	1561–4	2,860	2,550	2,900	2,610	2,910	2,629	2,770	2,716	2,720	2,743
Do	1561–2	2,805	2,020	3,010	3,200	3,060	2,761	2,612	3,007	2,810	2,809
Caloro	1561–1	3,904	1,730	2,610	2,533	2,497	2,761	2,748	2,597	2,426	2,673
Butte	1564	2,220	1,830	2,100	2,200	1,890	2,497	2,050	2,196	2,103	2,123
Fukuyama	2293	2,600	1,820	2,460	1,950	2,100	2,849	2,293	2,300	2,236	2,297
Selection No. 116	------	3,005	2,200	2,290	2,510	3,810	2,684	2,498	3,001	2,699	------
Selection No. 175	------	3,250	2,150	2,890	2,590	3,350	2,409	2,763	2,783	2,678	------
Selection No. 127	------	------	1,820	2,360	2,150	3,320	2,651	------	2,707	2,460	------
Selection No. 209	------	2,650	2,150	2,980	2,430	2,280	------	2,593	------	------	------
Selection No. 161	------	2,900	2,000	2,210	1,870	1,410	------	2,370	------	------	------
Selection No. 165	------	3,500	2,740	------	2,570	2,670	2,299	------	2,513	------	------
Selection No. 134	------	------	------	3,130	2,800	2,340	2,761	------	2,634	------	------
Early Wataribune	------	------	------	------	2,690	2,687	3,091	------	2,823	------	------
Late group:											
Selection No. 115	------	3,250	3,140	2,910	2,730	2,670	2,222	3,100	2,541	2,734	2,820
Selection No. 114	------	3,870	2,690	2,520	2,250	2,590	2,441	3,027	2,427	2,498	2,727
Wataribune	1561	2,854	2,410	2,380	2,400	2,270	2,310	2,548	2,327	2,354	2,437
Tse-Nishiki	2332	3,100	2,590	2,420	1,980	2,600	------	2,703	------	------	------
MEDIUM GRAIN											
Mid-season group:											
Early Prolific	------	3,260	1,680	2,040	1,660	2,030	2,101	2,327	1,930	1,902	2,129
LONG GRAIN											
Mid-season group:											
Selection No. 113	------	3,200	2,250	2,400	2,640	1,660	2,310	2,617	2,203	2,252	2,410
Lady Wright	------	------	------	------	1,380	2,190	2,409	------	1,993	------	------
Late group:											
Honduras	1643	2,350	1,580	1,710	2,000	2,050	1,749	1,880	1,933	1,818	1,907

Dividing the six-year period into shorter periods, it is seen that the general result is very similar.

During the first three-year period, 1919, 1920, and 1921, when grown on third-year and on fourth-year land, the short-grain mid-season variety Selection No. 1561–3 produced the highest average acre yield; during the second three-year period, 1922, 1923, and 1924, when grown on fifth-year and on sixth-year land, the variety Selection No. 1561–2, of the same group, was the leader. During both the first and second three-year periods the short-grain late group, represented by Selection No. 115, ranked second, and the long-grain mid-season group, represented by Selection No. 113, ranked third in yield. The only divergence from the six-year averages noted in the shorter periods is in the replacement of the medium-grain mid-season Early Prolific, occupying fourth place during the first three-year period, by the short-grain early group, represented by Colusa, during the second three-year period. The change in relative rank of these two groups during the second three-year period also was great enough to give a similar ranking for the five-year period from 1920 to 1924, inclusive.

The average yields of the highest producing mid-season and late short-grain rices during the six-year period from 1919 to 1924, inclusive, are nearly the same. The difference in average yield of the highest yielding varieties in these two groups is probably not significant. The highest yielding mid-season and late-maturing short-grain varieties, however, undoubtedly are superior to the mid-season medium-grain variety Early Prolific, the late long-grain variety Honduras, and the early short-grain variety Colusa, while the differences in the average yields of the three varieties last named are probably not significant.

On old rice land the mid-season and late-maturing short-grain varieties produce about the same average acre yields, whereas on new or rich land the late-maturing varieties are usually most productive. This indicates that with continued production the fertility factor is of some importance. On the soil at the station rice yields have been materially increased by the application of 100 pounds of ammonium sulphate per acre or by plowing under a bur-clover crop just before sowing the rice. This indicates that this soil (Stockton clay adobe) is somewhat deficient in nitrogen, at least to the extent that this plant food is a limiting factor in the yields of rice. If nitrogen is the limiting factor in rice production on this soil, and if there is only sufficient available nitrogen to produce an average acre yield of 3,000 pounds of paddy rice, then the mid-season short-grain varieties are as likely to produce a maximum yield as are the late short-grain varieties. That this assumption is correct is shown by the fact that varieties in either group are capable under suitable conditions of producing much higher average acre yields.

The leading commercial variety at the present time is Caloro, a short-grain mid-season rice. Next in importance is Early Wataribune, also of the short-grain mid-season group. The two short-grain early-maturing varieties, Colusa (C. I. No. 1600) and Onsen, also are of commercial importance. Caloro and Early Wataribune are grown both on new and old rice land; Colusa and Onsen are grown only on new land or on old land of high fertility. On most of the old rice lands the two latter varieties do not yield well because of their earliness.

Table 15 gives the average agronomic data for six varieties of rice grown at the station during the seven-year period from 1918 to 1924, inclusive. The average date of sowing was April 27, the average date of first irrigation was May 2, and the average date of emergence was May 17, except that for Caloro the date of seeding and emergence averaged one day later.

TABLE 15.—*Average agronomic data for six varieties of rice grown at the Biggs Rice Field Station during the seven-year period from 1918 to 1924, inclusive*

Type, groups, and variety	C. I. No.	Date of—						Height (inches)	From first irrigation to maturity (days)
		Seeding	First irrigation	Emergence	First heading	Full heading	Ripening		
SHORT GRAIN									
Early group:									
Colusa	1600	Apr. 27	May 2	May 17	Aug. 9	Aug. 23	Sept. 22	33	143
Mid-season group:									
Caloro	1561–1	Apr. 28	---do----	May 18	Aug. 22	Sept. 1	Oct. 5	33	156
Late group:									
Wataribune	1561	Apr. 27	---do----	May 17	Aug. 30	Sept. 8	Oct. 16	35	167
MEDIUM GRAIN									
Mid-season group:									
Early Prolific	--------	---do----	---do----	---do----	Aug. 20	Sept. 9	Oct. 11	35	162
LONG GRAIN									
Mid-season group:									
Selection No. 113	--------	---do----	---do----	---do----	Aug. 18	Sept. 3	Oct. 5	37	156
Late group:									
Honduras	1643	---do----	---do----	---do----	Aug. 29	Sept. 21	Oct. 19	38	170

The earliest variety, Colusa (C. I. No. 1600), was ripe on the average 143 days after the first irrigation, the average date of maturity being September 22. The Honduras variety required 170 days from the first irrigation to reach maturity, the average ripening date of this variety being October 19. Late Wataribune, which was grown extensively in California from 1912 to 1917, is comparatively late. The average date of ripening for this variety was October 16, or 167 days from first irrigation. In the year 1924 Caloro was grown more extensively in California than any other rice. The average date of ripening of Caloro was October 5, and the average number of days from the first irrigation to maturity was 156 days. Selection No. 113, a long-grain rice, also matures in 156 days, and Early Prolific is intermediate in maturity between Caloro and Wataribune, requiring 162 days from the first irrigation to reach maturity. The time elapsing from first irrigation to maturity for these varieties is shown graphically in Figure 7.

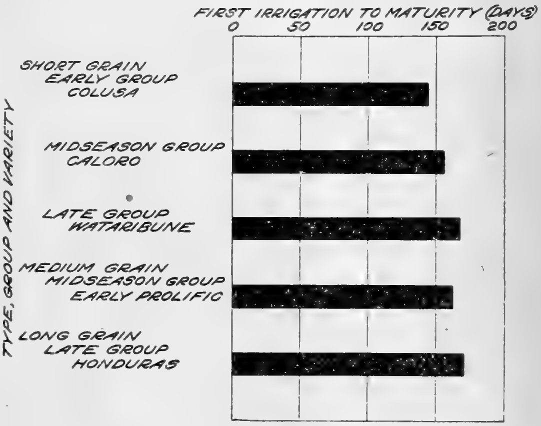

FIG. 7.—Average time (in days) from first irrigation to maturity for five standard rice varieties grown at the Biggs Rice Field Station during the 7-year period from 1918 to 1924, inclusive

Colusa is 13 days earlier than Caloro and 24 days earlier than Late Wataribune. Caloro is 11 days earlier than Late Wataribune and 14 days earlier than Honduras. The data in Table 15 were obtained from these varieties grown by the old method of irrigation. When grown by continuous submergence after broadcast seeding less time is required to reach maturity. The shortening of the required season varies from about 5 to 10 days, depending upon the date of seeding.

VARIETIES GROWN ON SMALL INCREASE PLATS

The yields of 17 varieties and strains of short-grain rice grown on small increase plats during the five-year period from 1920 to 1924, inclusive, are shown in Table 16. Of the 17 varieties 2 are early, 11 are mid-season, and 4 are late maturing.

Each year the increase varieties were grown on fallow land. In 1920 and 1921 the varieties were grown on single sixtieth-acre plats, in 1922 on single thirtieth-acre plats, in 1923 on single thirty-fourth-acre plats, and in 1924 on three thirty-third-acre plats.

During the four-year period from 1921 to 1924, inclusive, the highest average acre yields were produced by the mid-season rices, Selections No. 138, No. 139, No. 218, and No. 233. Selection No. 138 was not grown in 1920 and is not included in the five-year averages from 1920 to 1924, inclusive. During this period Selections Nos. 139, 218, and 233 of the same group were leaders. The average acre yield of Omachi (C. I. No. 2316), a late-maturing variety, was nearly as high as that of the highest yielding mid-season varieties for the five-year period. These results, like those from the varietal experiments on larger plats, show that the best mid-season short-grain varieties yield as well as those of the late short-grain group, if not a little better. The highest average acre yields in these experiments, as in the regular varietal experiments, were from mid-season short-grain varieties or selections of the Wataribune type.

TABLE 16.—*Yields of 17 varieties and selections of short-grain rice grown in small increase plats at the Biggs Rice Field Station during the five-year period from 1920 to 1924, inclusive*

Group and variety	C. I. No.	Acre yields (pounds)						
		1920	1921	1922	1923	1924	Average 1920 to 1924	Average 1921 to 1924
Early group:								
Eureka	--------	--------	--------	1,350	2,488	--------	--------	--------
Yosemite	--------	--------	--------	--------	2,686	1,996	--------	--------
Mid-season group:								
Selection No. 139	--------	3,498	3,000	2,970	3,638	3,217	3,265	3,206
Selection No. 218	--------	3,696	3,180	3,420	2,686	3,163	3,229	3,112
Selection No. 233	--------	3,531	3,120	3,480	2,788	2,937	3,171	3,081
Selection No. 178	--------	3,465	3.060	3,480	2,788	2,882	3,135	3,052
Selection No. 214	--------	3,267	3,000	3,000	2,448	3,234	2,990	2,920
Kokuryo-Miyako	2329	3,069	2,880	2,730	2,448	2,920	2,809	2,745
Selection No. 129	--------	2,574	2,700	3,180	2,584	2,788	2,765	2,813
Caloro	1561-1	[1] 1,730	2,760	2,910	2,796	3,333	[1]2,706	2,950
Selection No. 138	--------	--------	2,820	3,480	3,434	3,795	--------	3,382
Selection No. 171	--------	--------	2,820	3,240	2,958	3,102	--------	3,030
Selection No. 176	--------	--------	2,520	3,210	2,618	2,673	--------	2,755
Late group:								
Omachi	2316	3,432	3,300	3,750	2,788	2,376	3,129	3,053
Shiratama	2307	3,432	2,700	3,480	2,550	2,387	2,910	2,779
Takenari	2295	2,450	2,150	3,570	2,414	1,991	2,515	2,531
Takenaria	2338	--------	2,400	3,000	2,244	2,354	--------	2,499

[1] Yield from tenth-acre plat

In the varietal experiments on larger plats Selections No. 1561–2, No. 1561–3, and No. 1561–4, mid-season short-grain strains, and Selections No. 114 and 115, late short-grain strains, all produced higher six-year average yields than Caloro, which has so emphatically proved its value in commercial production. Likewise, in the increase plats several selections and three named varieties produced higher five-year average acre yields than Caloro. It is interesting to note, however, that all of the mid-season varieties which exceeded Caloro in average acre yield are morphologically the same as Caloro. In other experiments, reported hereafter, Caloro is one of the leading varieties, with higher yields than the varieties apparently superior in the experiments just discussed. These results at least indicate the general superiority of the type of which Caloro is representative for the general conditions of this section.

VARIETIES FOLLOWING GREEN-MANURE CROPS IN 1924

The land on which the green-manure crops were grown in 1923 was fallowed in 1922. In the spring of 1923 one variety of mung beans and four varieties of soy beans were sown in ridged rows about 3½ feet apart on a well-prepared seed bed. The beans were irrigated up and received a second irrigation on July 18. The mung beans grew to a height of about 5 feet and were matted on the ground when they were plowed under on November 1. The soy beans made a much poorer growth than the mung beans, although the Biloxi variety made a fairly good growth. The other varieties—Black Eyebrow, Easy Cook, and Peking—made a rather poor growth. The Biloxi variety was plowed under on November 1, and the other three varieties were double disked into the ground on the same date.

About an acre in all was sown to beans, and just west of this area, but separated from it by a dividing levee, was about one-half acre of land which was fallowed in 1922 and used in 1923 as a garden. The garden consisted mostly of tomatoes and melons grown in cultivated rows. The bean land and garden were kept free of weeds during the summer by cultivation and hand hoeing. The vines were removed from the garden in November, and an excellent volunteer stand of bur clover appeared. The bur clover made good growth during the winter and early spring months and stood about 15 inches high when it was plowed under late in March, 1924. The bean land also was shallow plowed in March and was double disked and dragged previous to seeding. A good seed bed was obtained on both the garden and the bean land.

On April 29, 14 varieties of rice were sown in triplicate thirty-third-acre plats on this land. The varieties were irrigated the first time on April 30. In all there were 42 thirty-third-acre plats, and of this number 16 were located on bur-clover land and 26 were located on mung-bean and soy-bean land. The yields obtained from the 14 varieties are shown in Table 17. The yields on bur-clover land are for single thirty-third-acre plats, except those of Selection No. 138 and C. I. No. 1600, which are the average of two thirty-third-acre plats. On the mung-bean and soy-bean land the yields are for two thirty-third-acre plats, except for Selection No. 138 and C. I. No. 1600, which are for single thirty-third-acre plats.

TABLE 17.—*Yields of 14 varieties of rice following green-manure crops at the Bigg Rice Field Station in 1924*

Type, group, and variety	C. I. No.	Acre yields (pounds)		
		Bur-clover land	Mung-bean and soy bean land	Difference in favor of bur-clover land
SHORT GRAIN				
Early group:				
Yosemite		3,960	1,996	1,964
Onsen		4,224	2,343	1,881
Colusa	1600	4,504	2,442	2,062
Mid-season group:				
Selection No. 176		5,676	2,673	3,003
Kokuryo-Miyako	2329	5,412	2,920	2,492
Caloro	1561-1	5,280	3,333	1,947
Selection No. 218		5,082	3,163	1,919
Selection No. 233		4,719	2,937	1,782
Selection No. 129		4,719	2,788	1,931
Selection No. 171		4,488	3,102	1,386
Selection No. 214		4,389	3,234	1,555
Selection No. 138		4,075	3,795	280
Selection No. 139		3,729	3,217	512
LONG GRAIN				
Early group: Nelson		5,049	2,475	2,574
Average		4,665	2,887	1,778

The increase in yields on bur-clover land range from 280 pounds per acre for Selection No. 138 to 3,003 pounds for Selection No. 176. The average increase for all varieties was 1,778 pounds per acre, or 38 per cent.

The yields obtained on the mung-bean and soy-bean land were but little, if at all, higher than are usual on ordinary fallow. This may have been due to the nitrogenous organic matter plowed under in November having been nitrified during the fall and winter months, the nitrates thus formed then being leached from the soil by spring rains and irrigation water preceding submergence and so lost for crop use. The bur-clover crop, on the other hand, was not plowed under early enough to permit rapid nitrification, due to the dry soil, and as a result the nitrogenous organic matter probably decomposed during the growing season and the nitrogen compounds formed as a result of this decomposition under water were in a form most available for the rice crop. At any rate, the result was a material increase in yields.

These results, although not necessarily conclusive, indicate that deficiency in available nitrogen is the factor which limits rice yields on the soil of the station farm. The data show that yields can be increased materially when rice is grown after a winter leguminous green-manure crop. The problem is to find a suitable legume which can be grown as a winter crop on the old rice lands for green-manure purposes. The use of nitrogenous fertilizers also may prove profitable in many cases.

NURSERY EXPERIMENTS

A large number of bulk varieties of rice from various countries, as well as many selections made from these bulk varieties, have been grown in the nursery experiments at the station. These varieties and selections have been grown in rod rows spaced 3 feet apart. The nursery was grown on fallow land and a good seed bed was prepared before seeding each year. From the several hundred varieties and selections tested at the station only three have been increased for commercial use: Colusa (C. I. No. 1600), Butte (C. I. No. 1564), and Caloro (C. I. No. 1561–1). A view of the rice nursery at the station is shown in Figure 8.

It is comparatively easy to obtain varieties or selections that have one or more desirable qualities, but it is more difficult to find one that possesses all the desirable qualities that would make it a popular variety with growers, millers, and consumers. From the standpoint of the growers earliness, high yield, stiff straw, and freedom from shattering are the important qualifications. Although freedom from shattering is essential, the variety must not be too hard to thresh. The miller desires a rice that mills well and is in demand on the market.

FIG. 8.—Rice nursery at the Biggs Rice Field Station

HEAD ROWS

Table 18 shows the annual and average yields, in pounds per row, of 63 varieties and selections grown in head rows during the six-year period from 1918 to 1923, inclusive. The rod rows were 3 feet apart, and the plants were spaced about 6 inches apart in the row. When the stand was perfect there were 33 plants in each row. Each row was a pure line, all seed having come from one plant or panicle.

In 1918, 1919, and 1920 Wataribune was used as a check, and in 1921, 1922, and 1923 the Caloro variety was used as a check.

Of the early short-grain varieties grown during the five-year period from 1918 to 1922, inclusive, an unnamed variety (C. I. No. 2116) produced an average yield distinctly higher than that of the nearest Wataribune check. For the six-year period from 1918 to 1923, inclusive, C. I. No. 2351, Colusa (C. I. No. 1600) a commercial variety, and C. I. No. 1587 all practically equaled the check in yield.

TABLE 18.—*Yields of 63 varieties of rice grown in head rows in the nursery experiments at the Biggs Rice Field Station during the six-year period from 1918 to 1923, inclusive*

[The circled figures represent the number of rows included where more than one was grown]

Type, group, and variety	C. I. No.	Yields per rod row (pounds)							
		1918	1919	1920	1921	1922	1923	Average 1918 to 1922	Average 1918 to 1923
SHORT GRAIN									
Wataribune	1561	2.50	2.00	2.12	0.87	(2) 1.75	(2) 1.00	1.85	1.71
Early group:									
Pakhasali Bhadai	1316	1.00	.75	1.75	.40	(2) 1.50	--------	1.08	--------
Spagnuolo	1585	1.20	2.25	1.75	1.00	(2) 1.75	(2) .75	1.59	1.45
Unnamed	1587	1.50	2.25	1.75	1.10	(2) 2.00	(2) .75	1.72	1.56
Colusa	1600	(4) .56	(4) 2.25	(4) 2.12	(4) 1.58	(2) 2.00	(2) .87	1.70	1.56
Bomba	2085	2.00	(2) 1.12	(2) 1.75	(2) 1.25	(2) 1.87	(2) .62	1.60	1.44
Wataribune	1561	2.25	1.87	1.87	.62	(2) 2.00	(2) .87	1.72	1.58
Unnamed	2116	2.50	2.25	1.75	2.00	(2) 2.87	--------	2.27	--------
Do	2298	1.75	2.00	2.00	1.00	(2) 1.62	--------	1.67	--------
Kinko	2299	1.25	2.00	1.50	[1] .50	(2) 1.25	--------	1.30	--------
Do	2302	1.62	1.60	1.50	.75	(2) 1.25	--------	1.34	--------
Shinshu-Kinko	2305	1.50	.75	1.50	.40	(2) 1.00	--------	1.03	--------
Wataribune	1561	2.50	1.75	2.00	.50	(2) 2.00	(2) .75	1.75	1.58
Aikoku	2306	1.62	1.50	2.00	1.00	(2) 1.50	--------	1.52	--------
Unnamed	2309	1.00	1.00	1.25	[1] .40	(2) 1.00	--------	.93	--------
Do	2310	1.20	.75	1.50	[1] .50	(2) 1.50	--------	1.09	--------
Geppu	2311	1.50	1.00	1.50	[1] .60	(2) 1.62	--------	1.24	--------
Do	2313	1.50	.75	1.50	[1] .25	(2) 1.25	(2) .62	1.05	.98
Wataribune	1561	2.62	2.00	1.87	.87	(2) 2.00	(2) .87	1.87	1.70
Unnamed	2351	1.25	2.00	2.25	1.50	(2) 2.00	(2) 1.50	1.80	1.75
Mid-season group:									
Nugengwa	1436	2.12	1.25	1.75	1.50	(2) 2.25	(2) 1.12	1.77	1.67
Butte	1564	(3) 1.25	(3) 2.25	(3) 1.67	(3) 1.33	(2) 2.25	(2) 1.00	1.75	1.63
Tshijiro	2304	1.25	1.75	2.00	1.00	(2) 1.50	(2) .75	1.50	1.38
Araki	2312	1.50	1.25	1.50	1.00	(2) 1.87	(2) .50	1.42	1.27
Wataribune	1561	2.25	2.25	1.37	1.50	(2) 1.87	(2) 1.37	1.85	1.77
Bujen-ho	2322	(3) 2.33	(3) 2.00	(3) 2.58	(3) 1.33	(2) 2.25	(2) 1.00	2.10	1.92
Tama-Nishiki	2323	1.25	2.00	2.00	1.50	(2) 2.12	(2) 1.00	1.77	1.65
Araki	2336	1.50	2.25	1.50	.75	(2) 2.12	(2) 1.00	1.62	1.52
Unnamed	2337	2.50	2.25	2.25	1.25	(2) 2.25	(2) 1.62	2.10	2.02
Sekitori	2342	2.12	2.00	1.75	1.00	(2) 1.62	(2) 1.37	1.70	1.64
Wataribune	1561	2.37	2.25	1.50	1.62	(2) 1.87	(2) 1.87	1.92	1.91
Unnamed	2343	2.00	1.75	2.00	1.00	(2) 1.75	(2) 1.37	1.70	1.65
Aikoku	2361	1.50	2.00	1.50	1.00	(2) 1.75	(2) 1.37	1.55	1.52
Late group:									
Unnamed	1244	2.00	1.00	1.25	.40	(2) 1.75	--------	1.28	--------
Makuno Uchi	1308	2.25	1.25	1.50	.50	(2) 1.87	(2) 1.37	1.47	1.46
Unnamed	1428	2.00	2.00	1.75	1.75	(2) 2.25	(2) 1.87	1.95	1.94
Wataribune	1561	2.00	2.12	1.62	1.50	(2) 2.00	(2) 2.12	1.85	1.89
Unnamed	1465	2.25	2.00	1.50	1.75	(2) 2.12	(2) 1.37	1.92	1.83
Wataribune	1561	(5) 2.25	(6) 2.00	(6) 1.80	2.25	(2) 2.87	(2) 1.50	2.23	2.11
Unnamed	1925	[2] 0	3.00	3.00	2.00	(2) 2.87	(2) 1.12	2.17	2.40
Aitoku	2290	2.25	1.00	2.00	1.75	(2) 2.25	(2) 1.25	1.85	1.75
Unnamed	2291	1.75	1.50	2.00	1.50	(2) 2.37	(2) 1.12	1.82	1.71
Wataribune	1561	1.87	3.00	1.87	1.50	(2) 2.25	(2) 1.87	2.10	2.06
Takenari	2301	2.25	2.00	2.00	1.50	(2) 1.75	(2) .87	1.90	1.73
Miyako	2303	1.75	2.50	2.75	1.50	(2) 2.00	(2) 1.00	2.10	1.92
Kibi	2326	2.25	1.75	1.50	2.25	(2) 2.12	(2) .87	1.97	1.79
Takenari	2338	2.50	2.25	2.00	1.00	(2) 2.00	(2) 1.62	1.95	1.90
Usa-Nishiki	2339	3.00	2.75	2.00	1.50	(2) 2.25	(2) 1.87	2.30	2.23
Wataribune	1561	2.37	4.25	2.37	1.75	(2) 2.37	(2) 1.25	2.62	2.39
Wase-Shinriki	2346	2.25	2.25	2.25	1.50	(2) 2.25	(2) 1.75	2.10	2.04
Unnamed	2350	1.75	3.00	2.00	1.75	(2) 2.25	(2) 2.00	2.15	2.13
Yamato-Nishiki	2355	2.25	3.25	1.75	1.50	(2) 2.00	(2) 2.12	2.15	2.15
Unnamed	2356	2.00	2.50	1.75	1.50	(2) 2.37	(2) 1.87	2.02	2.00
Yamadako	2357	2.25	2.50	1.75	1.50	(2) 2.12	(2) 1.62	2.02	1.96
Wataribune	1561	2.50	4.25	2.37	2.00	(2) 2.00	(2) 1.25	2.62	2.40
Unnamed	2359	2.50	2.25	2.25	1.75	(2) 2.25	(2) 2.50	2.20	2.25
Do	2360	2.50	2.75	2.25	1.50	(2) 1.87	--------	2.17	--------

[1] Yield reduced by birds about 50 per cent.
[2] Only one plant obtained; not included in averages.

TABLE 18.—*Yields of 63 varieties of rice grown in head rows in the nursery experiments at the Biggs Rice Field Station during the six-year period from 1918 to 1923, inclusive*—Continued

Type, group, and variety	C. I. No.	Yields per rod row (pounds)							
		1918	1919	1920	1921	1922	1923	Average	
								1918 to 1922	1918 to 1923
MEDIUM GRAIN									
Early group:									
Nun Key	1334	2.00	1.50	2.25	1.50	② 2.25	----------	1.90	--------
Unnamed	2119	2.25	2.00	1.50	1.50	② 2.25	② 1.12	1.90	1.77
Do	2120	2.25	1.75	1.25	.75	② 2.12	----------	1.62	--------
Wataribune	1561	2.37	3.00	2.50	1.62	② 1.62	② 1.25	2.22	2.06
Unnamed	2151	2.25	1.75	1.50	1.00	② 2.50	----------	1.80	--------
Late group:									
Sam Sai	1331	2.75	1.75	1.75	1.75	② 2.37	----------	2.07	--------
LONG GRAIN									
Early group:									
Jippon Tsu	1338	1.62	1.25	1.50	1.25	② 2.00	② 1.00	1.52	1.44
Late group:									
Unnamed	1241	③ 1.92	③ 1.50	③ 1.08	③ .25	② 1.12	----------	1.17	--------
Do	1258	③ 2.25	③ .75	③ 1.42	③ .37	② 1.62	----------	1.28	--------
Wataribune	1561	2.25	2.50	3.00	1.12	② 1.75	② 1.12	2.12	1.96
Unnamed	1288	2.25	1.25	2.25	.25	② 1.87	----------	1.57	--------
Laer Chap	1322	2.00	1.00	1.50	.50	② 1.75	----------	1.35	--------
Unnamed	1546	2.00	2.00	1.75	1.25	② 2.12	----------	1.82	--------
Do	1577	2.50	2.25	1.50	1.50	② 2.37	----------	2.02	--------
Honduras	1643	② 1.12	② .75	② 2.12	② .62	② 2.25	② 1.12	1.37	1.33
Wataribune	1561	2.37	2.50	2.50	1.12	② 1.62	② 1.25	2.02	1.89
Carolina White	1644	2.00	.25	2.50	.87	② 2.12	② 1.25	1.55	1.50
Carolina Gold	1645	1.00	.50	2.25	1.00	② 2.25	② 1.00	1.40	1.33
Unnamed	2155	2.50	2.25	1.75	2.50	② 2.62	----------	2.32	--------
Wataribune	1561	2.50	2.12	1.75	1.12	② 1.12	② 1.62	1.72	1.70

During the five-year period from 1918 to 1922, inclusive, and the six-year period from 1918 to 1923, inclusive, the short-grain mid-season varieties Bujen-ho (C. I. No. 2322) and the unnamed C. I. No. 2337 both produced higher average yields per row than the nearest checks. Other comparatively high-yielding mid-season short-grain varieties during the six-year period were Sekitori (C. I. No. 2342), (C. I. No. 2343), and Tama-Nishiki (C. I. No. 2323).

Of the late short-grain varieties grown during the six-year period from 1918 to 1923, inclusive, the four leading varieties were C. I. No. 1925, C. I. No. 2359, Usa-Nishiki (C. I. No. 2339), and Yamato-Nishiki (C. I. No. 2355). Other high-yielding varieties include C. I. No. 2350, Wataribune (C. I. No. 1561), and Wase-Shinriki (C. I. No. 2346).

Of the early-maturing and late-maturing medium-grain rices grown during the five-year period from 1918 to 1922, inclusive, none equaled the nearest check in yield. Sam Sai (C. I. No. 1331), a late variety, and Nun Key, an early variety, were the highest yielding varieties of this general type.

Jippon Tsu (C. I. No. 1338) was the only early long-grain variety grown during the five-year period from 1918 to 1922, and it yielded considerably less than the nearest check. During this period the unnamed C. I. No. 2155, a late-maturing long-grain variety, exceeded the average yields of the nearest check. All other varieties of this group, except C. I. No. 1577, were distinctly inferior in yield.

TABLE 19.—*Yields of 115 varieties and selections of rice grown in bulk rows in the nursery experiments at the Biggs Rice Field Station during the six-year period from 1918 to 1923, inclusive*

[The circled figures represent the number of rows included where more than one was grown. All the varieties and selections grown were short-grained rices, except Selection No. 113, a midseason long grain rice; Edith, a late-maturing long-grain variety; and Selection No. 133, a midseason medium-grain variety]

Group and variety	C. I. No.	Selection No.	Yield per row (pounds)							
			1918	1919	1920	1921	1922	1923	Average 1920 to 1922	Average 1918 to 1923
Check	------	------	(2) 3.12	(2) 2.37	(2) 1.75	(2) 1.62	(2) 2.12	(3) 1.87	1.83	2.14
Early group:										
Sue Hero	------	------	---------	---------	2.00	[1] .75	(2) 1.75	(1) 1.75	1.50	------
Onsen	------	------	---------	---------	1.50	1.00	(2) 1.75	(2) 1.87	1.42	------
Unnamed	2179	------	---------	---------	2.00	.50	(2) 1.50	(1) 1.75	1.33	------
Do	1992	------	2.75	2.00	2.25	1.00	(2) 2.00	(2) 1.75	1.75	1.96
Do	2008	------	(2) 2.92	3.33	2.75	.75	(2) 2.00	(2) 1.62	1.83	2.23
Mid-season group:										
Unnamed	-----	111	(2) 3.00	(2) 3.62	(2) 3.00	(2) 1.37	(2) 2.25	(2) 1.87	2.21	2.52
	-----	112	(3) 2.62	(3) 3.42	(3) 3.08	(3) 1.33	(2) 2.37	(2) 2.00	2.26	2.47
	-----	116	(3) 3.17	(3) 3.33	(3) 3.50	(3) 1.50	(2) 1.87	(2) 2.12	2.29	2.58
Check	------	------	(2) 4.00	(2) 3.12	(2) 3.12	(2) 1.62	(2) 2.12	(2) 1.87	2.29	2.64
Unnamed	-----	117	3.25	3.75	2.50	1.50	(2) 1.50	(2) 1.62	1.83	2.35
	-----	118	3.50	4.50	2.75	1.75	(2) 1.62	(2) 1.75	2.04	2.65
	-----	119	2.75	3.25	2.75	2.00	(2) 1.62	(2) 1.62	2.12	2.33
	-----	120	2.75	3.75	2.75	2.00	(2) 1.75	(2) 1.87	2.17	2.48
	-----	122	2.75	3.75	2.50	2.00	(2) 2.00	(2) 1.75	2.17	2.46
	-----	123	3.00	3.75	2.50	2.25	(2) 2.12	(2) 1.75	2.29	2.56
	-----	124	3.00	3.50	2.25	2.00	(2) 2.25	(2) 2.00	2.17	2.50
	-----	125	2.75	4.25	2.00	2.00	(2) 2.12	(2) 2.00	2.04	2.52
Check	------	------	(2) 4.00	(2) 3.62	(2) 2.62	(2) 2.37	(2) 1.75	(2) 2.00	2.25	2.73
Unnamed	-----	126	2.75	4.00	2.25	1.75	(2) 2.12	(2) 1.87	2.04	2.46
	-----	127	(4) 3.00	(4) 3.62	(4) 3.31	(4) 2.00	(2) 2.12	(2) 2.37	2.48	2.74
	-----	129	2.75	3.50	2.75	1.75	(2) 1.87	(2) 1.75	2.12	2.40
	-----	131	3.50	4.00	4.00	1.75	(2) 2.25	(2) 2.00	2.67	2.92
	-----	132	2.75	3.75	3.25	1.50	(2) 1.75	(2) 1.50	2.17	2.42
	-----	138	(3) 2.58	(3) 4.17	(3) 2.92	(3) 2.00	(2) 2.12	(2) 2.00	2.35	2.63
	-----	139	(3) 2.83	(3) 3.83	(3) 2.83	(3) 1.75	(2) 1.87	(2) 2.00	2.15	2.52
	-----	141	(2) 3.00	(2) 3.50	(2) 3.00	(2) 1.62	(2) 1.75	(2) 2.87	2.12	2.62
Check	------	------	(2) 3.12	(2) 4.12	(2) 2.62	2.00	(2) 1.75	(2) 2.25	2.12	2.64
Unnamed	-----	142	2.50	4.00	3.00	2.00	(2) 1.75	(2) 2.00	2.25	2.54
	-----	146	3.00	4.50	2.50	2.00	(2) 2.00	(2) 2.12	2.17	2.69
	-----	147	3.75	4.00	3.00	2.00	(2) 2.12	(2) 2.12	2.37	2.83
	-----	149	2.75	2.75	2.50	1.50	(2) 1.50	(2) 1.87	1.83	2.15
	-----	151	(3) 2.83	(3) 3.33	(3) 2.75	(3) 1.67	(2) 1.75	(2) 1.75	2.06	2.35
	-----	153	3.00	2.75	2.50	1.75	(2) 1.87	(2) 2.00	2.04	2.31
	-----	155	(3) 3.00	(3) 2.92	(3) 3.08	(3) 1.67	(2) 1.62	(2) 2.00	2.12	2.38
	-----	158	(3) 2.50	(3) 2.42	(3) 2.70	(3) 1.42	(2) 1.75	(2) 1.75	1.96	2.09
Check	------	------	(2) 3.75	(2) 3.62	(2) 2.12	(2) 1.87	(2) 1.75	(2) 2.12	1.91	2.54
Unnamed	-----	162	2.50	3.25	2.00	1.50	(2) 2.00	(2) 2.00	1.83	2.21
	-----	165	(5) 2.75	(3) 3.00	(3) 2.83	(3) 1.67	(2) 2.00	(2) 2.12	2.17	2.40
	-----	167	2.50	3.00	2.00	1.50	(2) 2.25	(2) 2.12	1.92	2.23
	-----	168	(3) 2.87	(2) 3.00	2.75	(3) 1.42	(2) 2.25	(2) 1.87	2.14	2.36
	-----	170	(5) 2.69	(4) 3.06	3.00	(4) 1.62	(2) 2.12	(2) 2.12	2.25	2.43
	-----	172	2.75	2.75	2.25	2.25	(2) 2.12	(2) 1.87	2.21	2.33
	-----	174	(3) 2.50	(3) 3.50	(3) 2.58	(3) 1.83	(2) 2.25	(2) 2.12	2.22	2.46
	-----	175	(6) 2.75	3.20	(5) 2.90	(5) 2.05	(2) 2.25	(2) 2.12	2.40	2.55
Check	------	------	(2) 3.50	(2) 3.25	(2) 2.50	(2) 1.25	(2) 1.75	(2) 2.00	1.83	2.38
Unnamed	-----	178	(3) 2.25	(4) 2.94	(4) 3.44	(4) 2.12	(2) 2.25	(2) 2.00	2.60	2.50
	-----	184	2.00	3.50	2.00	3.00	(2) 2.25	(2) 2.00	2.42	2.46
	-----	185	2.25	4.25	2.00	3.25	(2) 2.25	(2) 1.87	2.50	2.65
	-----	190	3.00	4.00	2.75	1.75	(2) 2.12	(2) 2.12	2.21	2.62
	-----	204	2.50	3.50	2.50	2.00	(2) 2.00	(2) 1.75	2.17	2.38
	-----	208	2.12	4.00	3.50	1.10	(2) 2.87	(2) 1.75	2.49	2.56
	-----	209	2.50	4.00	3.00	1.25	(2) 2.87	(2) 1.62	2.37	2.54
	-----	210	2.00	3.25	2.50	1.50	(2) 2.50	(2) 2.12	2.17	2.31
Check	------	------	(2) 3.62	(2) 3.00	(2) 2.12	1.87	(2) 1.75	(2) 2.00	1.91	2.39
Unnamed	-----	211	2.50	4.00	2.75	1.75	(2) 2.87	(2) 2.12	2.46	2.67
	-----	212	2.75	4.75	3.75	1.50	(2) 2.25	(2) 2.00	2.50	2.83
	-----	213	3.00	4.50	3.50	1.25	(2) 2.25	(2) 2.00	2.33	2.75
	-----	214	2.00	3.75	3.75	1.60	(2) 1.87	(2) 1.75	2.41	2.45
	-----	217	2.75	4.50	3.50	2.00	(2) 1.87	(2) 1.75	2.46	2.73
	-----	218	2.75	3.75	3.25	1.25	(2) 2.12	(2) 2.00	2.21	2.52
	-----	219	3.00	4.75	3.25	1.75	(2) 2.87	(2) 2.12	2.62	2.96
	-----	221	3.00	4.75	3.25	2.00	(2) 2.12	(2) 2.12	2.46	2.87

[1] Yield reduced about 50 per cent by birds.

TABLE 19.—*Yields of 115 varieties and selections of rice grown in bulk rows in the nursery experiments at the Biggs Rice Field Station during the six-year period from 1918 to 1923, inclusive*—Continued

Group and variety	C. I. No.	Selection No.	Yield per row (pounds) 1918	1919	1920	1921	1922	1923	Average 1920 to 1922	Average 1918 to 1923
Mid-season group—Continued.										
Check			(2) 3.25	(2) 3.12	(2) 2.25	(2) 2.37	(2) 1.75	(2) 2.12	2.12	2.48
Unnamed		222	2.50	5.25	2.75	2.00	(2) 2.12	(2) 2.00	2.29	2.77
		233	3.00	4.75	3.00	2.25	(2) 2.12	(2) 2.37	2.46	2.91
Fukuyama	2293		(5) 3.85	(4) 3.20	2.25	1.25	(2) 1.87	(2) 1.75	1.79	2.36
Goka-Wase	2315		3.75	3.50	2.50	1.50	(2) 1.87	(2) 1.87	1.96	2.50
Sekitori	2320		3.37	3.12	2.50	1.75	(2) 1.62	(2) 1.50	1.96	2.31
Sugaippon	2321		3.25	3.25	2.50	1.50	(2) 1.62	(2) 1.75	1.87	2.31
Kokuryo-Miyako	2329		(6) 3.25	(4) 3.37	2.50	1.50	(2) 2.00	(2) 2.00	2.00	2.44
Gunyeki	2331		3.00	3.25	2.25	1.50	(2) 2.25	(2) 2.00	2.00	2.38
Check			(2) 2.67	(2) 3.12	(2) 2.12	(2) 1.87	(2) 1.87	(2) 2.12	1.95	2.30
Kokuryo-Miyako	2335		3.00	2.75	2.25	1.50	(2) 2.00	(2) 2.00	1.92	2.25
Early Wataribune	1561-3		3.75	3.50	2.25	1.50	(2) 2.37	(2) 2.50	2.04	2.65
Do	1561-4		3.50	3.00	2.25	1.25	(2) 2.25	(2) 2.25	1.92	2.42
Late group:										
Unnamed		107	(2) 3.00	(2) 3.00	(2) 2.87	(2) 1.55	(2) 2.00	(2) 1.87	2.14	2.38
		114	(5) 3.20	(5) 3.75	(5) 3.34	(5) 1.60	(2) 2.00	(2) 1.87	2.31	2.63
		115	(5) 3.90	(5) 3.40	(5) 3.75	(5) 1.72	(2) 2.12	(2) 2.00	2.53	2.82
		140	3.50	3.75	3.00	2.00	(2) 1.75	(2) 1.75	2.25	2.63
		187	2.00	3.50	3.75	2.25	(2) 2.67	(2) 2.12	2.89	2.72
Check			(2) 3.87	(2) 4.87	(2) 3.12	(2) 1.75	(2) 2.00	(2) 2.00	2.29	2.94
Unnamed		188	2.25	4.25	3.75	2.00	(2) 2.25	(2) 2.00	2.67	2.75
		189	2.75	4.00	3.50	2.25	(2) 2.25	(2) 2.25	2.67	2.83
		205	3.25	3.75	2.50	2.00	(2) 2.00	(2) 2.00	2.17	2.58
		206	4.00	4.25	3.25	2.25	(2) 2.37	(2) 2.00	2.62	3.02
		207	3.12	4.50	3.25	1.25	(2) 2.87	(2) 1.75	2.46	2.79
		216	3.50	4.00	3.75	2.00	(2) 1.87	(2) 1.87	2.54	2.83
Wataribune	1561		3.62	4.87	3.00	1.75	(2) 2.87	(2) 2.25	2.54	3.06
Unnamed	2030		(3) 4.31	(3) 3.75	3.25	(2) 2.02	(2) 2.50	(2) 2.12	2.59	2.99
Check			3.62	4.87	3.00	1.75	(2) 2.00	(2) 1.87	2.25	2.85
Unnamed	2033		3.25	3.00	1.62	1.00	(2) 1.75	(2) 1.37	1.46	2.00
Do	2294		4.75	3.50	2.50	1.50	(2) 2.12	(2) 1.75	2.04	2.69
Takenari	2295		(2) 4.08	(2) 3.42	3.00	1.67	(2) 2.00	(2) 1.50	2.22	2.61
Shinriki	2300		4.87	3.35	2.00	1.50	(2) 2.75	(2) 1.75	2.08	2.70
Shiratama	2307		4.00	3.50	2.00	1.75	(2) 2.25	(2) 1.75	2.00	2.54
Omachi	2316		4.25	4.00	3.00	2.00	(2) 1.75	(2) 2.00	2.25	2.83
Shinriki	2319		4.00	3.50	2.75	2.25	(2) 2.00	(2) 2.12	2.33	2.77
Tse-Nishiki	2332		3.50	3.00	2.50	1.75	(2) 2.00	(2) 1.87	2.08	2.44
Check			3.75	4.50	2.12	1.50	(2) 2.00	(2) 1.87	1.87	2.62
Samba	2348		4.00	3.25	2.75	1.50	(2) 2.00	(2) 2.25	2.08	2.63
Selection		113	(4) 3.37	(4) 3.62	(4) 3.19	(4) 1.56	(2) 2.50	(2) 2.12	2.42	2.73
Do		133	3.12	3.75	2.75	2.25	(2) 1.62	(2) 1.87	2.21	2.56
Edith	2127		(2) 3.37	(3) 1.83	2.00	2.25	(2) 1.50	(2) 2.00	1.92	2.16
Unnamed	5306				3.00	1.50	(2) 2.25		2.25	
	5307				3.50	1.75	(2) 2.50		2.58	
	5310				2.50	2.00	(2) 2.25		2.25	
	5311				2.75	1.25	(2) 2.25		2.08	
	5312				2.50	1.10	(2) 2.50		2.03	
	5315				2.50	1.50	(2) 2.75		2.25	
	5316				2.50	2.00	(2) 2.00		2.17	
	5320				2.50	1.25	(2) 2.25		2.00	
	5322				3.00	1.50	(2) 2.25		2.25	
	5323				2.50	2.00	(2) 2.00		2.17	
	5326				2.50	1.50	(2) 2.25		2.08	
	5327				2.50	1.25	(2) 2.25		2.00	
	5328				2.75	1.50	(2) 2.75		2.33	
	5329				2.75	1.50	(2) 2.50		2.25	
	5331				2.50	2.25	(2) 2.25		2.33	
	5336				2.50	1.50	(2) 2.50		2.17	
	5337				2.50	1.75	(2) 2.75		2.33	
	5338				2.75	1.25	(2) 2.50		2.17	
	5340				2.00	2.00	(2) 2.50		2.17	
	5341				2.25	1.30	(2) 2.75		2.10	
	5344				1.75	1.25	(2) 2.00		1.67	
	5345				1.50	1.50	(2) 1.50		1.17	
	5346				1.50	.75	(2) 2.00		1.42	

BULK ROWS

Table 19 shows the annual and average yields in pounds per rod row for 115 varieties and selections grown in bulk rows in the nursery. These varieties, except new importations, are pure-line varieties or selections. The rows were seeded at approximately the same rate as that used on commercial fields. The yields of the check rows are for the Wataribune variety in 1918, 1919, and 1920, and for the Caloro variety in 1921, 1922, and 1923. As a rule the bulk rows have yielded better than the head rows, partly because of heavier seeding and better stands.

All the varieties and selections grown during the entire six-year period from 1918 to 1923, inclusive, were short-grain rices, except Selection No. 113, a mid-season long-grain rice; Edith, a late-maturing long-grain variety; and Selection No. 133, a mid-season medium-grain variety. Only two early short-grain varieties, C. I. No. 1992 and C. I. No. 2008, were grown during the entire six-year period, and both are comparatively low in rank.

During the six-year period from 1918 to 1923, inclusive, many of the mid-season short-grain selections gave higher average yields than the nearest checks. The seven highest yielding mid-season short-grain selections were Nos. 219, 212, 233, 221, 222, 131, and 147, these varieties outyielding the nearest check by 0.48, 0.44, 0.43, 0.39, 0.29, 0.19, and 0.19 pounds per row, respectively. Ten mid-season short-grain selections gave average yields equal or superior to the average yield of the highest yielding check included within this group.

Of the late short-grain varieties and selections grown during the six-year period six varieties produced higher average yields than the nearest check. The highest yielding varieties were Wataribune (C. I. No. 1561), C. I. No. 2030, and Selection No. 206, exceeding the average yield of the nearest check by 0.21, 0.14, and 0.08 pounds per row, respectively.

The mid-season long-grain Selection No. 113 was slightly superior to the check in yield; the medium-grain Selection No. 133 and the late long-grain variety Edith were both inferior to the check.

The 23 unnamed varieties grown only in 1920, 1921, and 1922, and designated by C. I. numbers from 5306 to 5346, are all medium-grain rices. Many of these varieties mature early and yield well, but owing to weak straw (lodging) and shattering they are of no commercial promise. However, some of these varieties, because of heavy stooling, early maturity, and good yields, should be of value as breeding material.

SUMMARY

The soil on the Biggs Rice Field Station is Stockton clay adobe a dark-gray to black clay which is typical of a large area on which rice is grown in the Sacramento Valley.

The summer months are hot and the winter months are cool, with occasional freezes. June, July, and August are usually hot. A daily range in temperature of 40° F. is common during the growing season.

The average annual precipitation from 1913 to 1924 was 20.85 inches. December, January, and February are the three months of greatest rainfall.

Strong winds sometimes blow from the north or the south, but as a rule there is little wind.

The average evaporation for June, July, and August from 1913 to 1924, inclusive, was 24.834 inches. The average evaporation from April to October, inclusive, for 1914, 1915, 1921, 1922, and 1923 was 42.090 inches.

On foul land rice sown broadcast and immediately and continuously submerged or sown broadcast in the water and kept submerged thereafter appears to have three distinct advantages over rice irrigated in the old way: (1) Continuous submergence controls to a marked extent the common forms of water grass and also sprangletop, and the rice plants so irrigated are more vigorous and thrifty than those grown by the old method of irrigation; (2) depending upon the date of seeding, the rice matures from 5 to 10 days earlier than when irrigated in the old way, the difference being less from early than from late dates of seeding; (3) as a result of water-grass control and better developed rice plants, the acre yields are materially increased by continuous submergence, and because of earlier maturity the danger of crop loss by early fall rains is lessened.

The results in the date-of-seeding and depth-of-seeding experiments indicate that the rice should be sown broadcast comparatively early and immediately submerged about 6 inches.

Experimental results indicate that seeding in the water has no advantages over seeding on the soil, except that usually less seed is required to obtain good stands. The increased cost of sowing in the water, however, more than offsets any saving in seed.

When rice is drilled and immediately submerged it appears that considerable seed rots, this often resulting in poor stands and low yields. When stands of rice are poor such weeds as the annual sedge, redstem, and cat-tail increase rapidly.

When rice is drilled or sown broadcast and irrigated and drained at frequent intervals until emergence and then is continuously submerged, shallow submergence at 2 and 4 inches does not effectively control water grass. Deep submergence 6 and 8 inches aids in the control of water grass, but such depths of submergence also suffocate so much rice that low yields are produced. This method of irrigation is distinctly inferior to continuous submergence, both in the control of water grass and in yields of rice.

The results show that it does not pay to grow rice on a seed bed prepared merely by double disking rice stubble land, because such weeds as spike rush, cat-tail, slender aster, canary grass, and perennial sedge reduce yields below profitable limits. Good plowing aids materially in the control of these weeds. During the three years 1922, 1923, and 1924 the average acre yield of the spring-plowed land was 754 pounds more than for the disked stubble land.

The results of the rate-of-seeding and method-of-irrigation experiments show that the best method of irrigation on foul land consists of continuous submergence after broadcasting the rice on the soil. The results also indicate that probably rice should be sown at a heavier rate when grown by continuous submergence than when grown by deferred submergence by the old method of irrigation.

The results of rate-of-seeding experiments with three varieties indicate that on old land rice probably should be sown at the rate of 150 pounds per acre when grown by the old method of irrigation.

The results of the experiments on seed-bed preparation for rice grown by continuous submergence show that the best yields were obtained on well-prepared seed beds on which the rice was sown broadcast and immediately submerged 4 to 6 inches. On unprepared or poorly prepared seed beds such weeds as spike rush, cat-tail, and slender aster reduce rice yields below profitable limits.

The results show that on land foul with cat-tail, a heavy rate of seeding (200 pounds per acre) does not help to eradicate it. Good stands of rice do aid, however, in preventing cat-tail from becoming established on a clean rice field.

The results of continuous cropping to rice indicate that profitable yields can not be obtained for more than six years in succession by the old methods of irrigation, even when weeds are kept under control, and that continuous cropping probably will not be practicable when irrigating by continuous submergence.

The varietal experiments show that medium-grain and long-grain rices are not so well adapted to California conditions as the short-grain rices. During the six-year period from 1919 to 1924, inclusive, Selection No. 1561-3, a mid-season short-grain rice with an average acre yield of 2,971 pounds, was the highest-yielding variety. Selection No. 115, a late short-grain rice, produced an average acre yield for the same period of 2,820 pounds. For the same period Selection No. 113, a mid-season long-grain variety, and Early Prolific, a mid-season medium-grain variety, produced average acre yields of 2,410 and 2,129 pounds, respectively.

Colusa (C. I. No. 1600), an early-maturing short-grain variety, matures in 143 days from the date of the first irrigation; Caloro, a mid-season variety, in 156 days; and Wataribune (C. I. No. 1561), a late short-grain variety, in 167 days when irrigated by the old method.

Of 17 varieties and selections of early, mid-season, and late short-grain rices grown on small increase plats from 1920 to 1924, inclusive, the highest average yields were produced by mid-season selections, the late group ranking second in yield.

The average increase in yield of 14 varieties grown on bur-clover land when compared with the same varieties grown on mung-bean and soy-bean land was 1,778 pounds per acre, or 38 per cent.

The yield of 63 varieties grown in head rows and also 115 varieties grown in bulk rows in the rice nursery from 1918 to 1923, inclusive, are presented. Bulk rows produced higher average yields per row than head rows, apparently because of heavier seeding. In general, mid-season and late short-grain varieties and selections gave higher average yields in the nursery than the medium or long grain types.

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March 2, 1926

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