California Agricultural Extension
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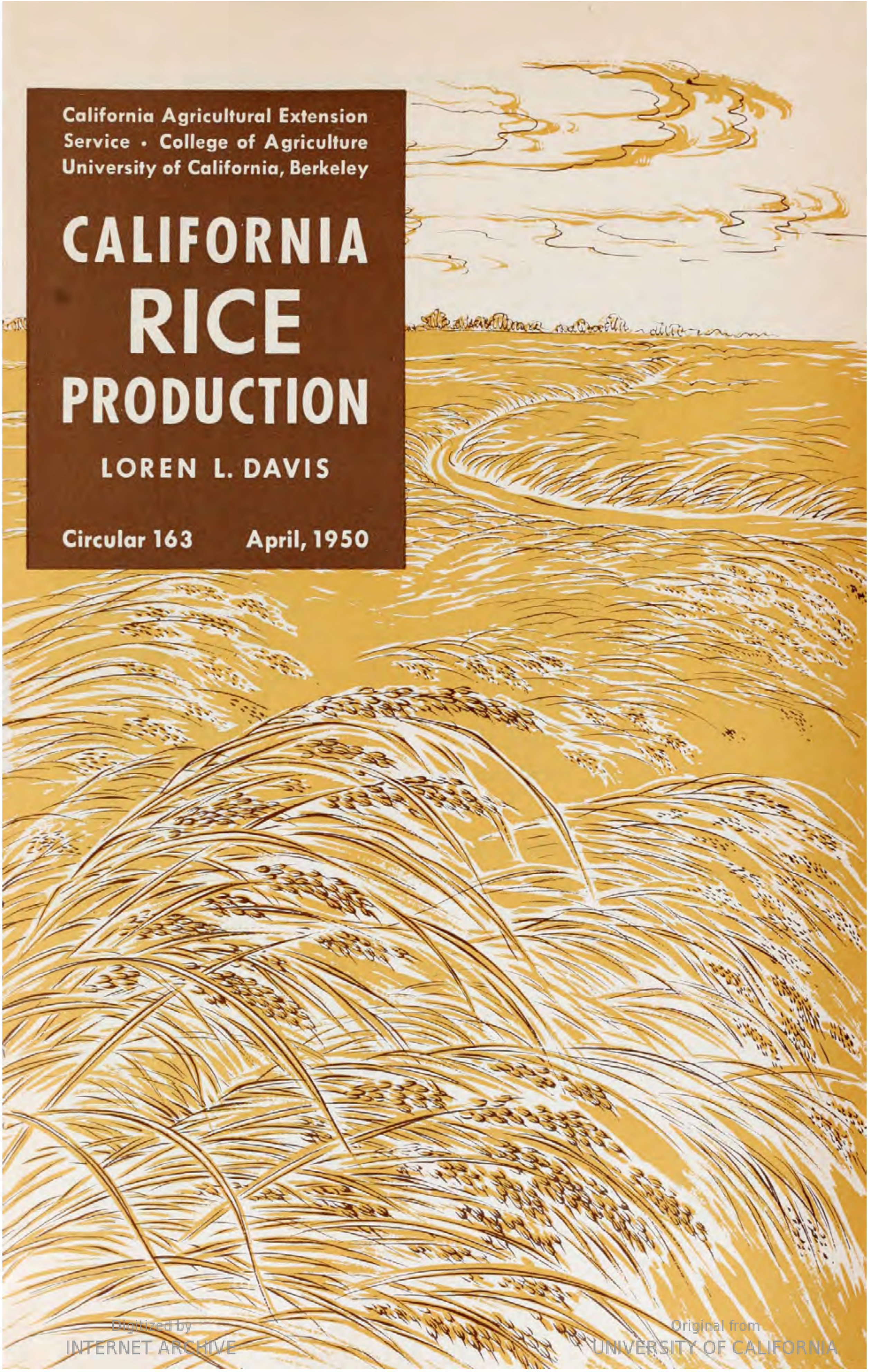
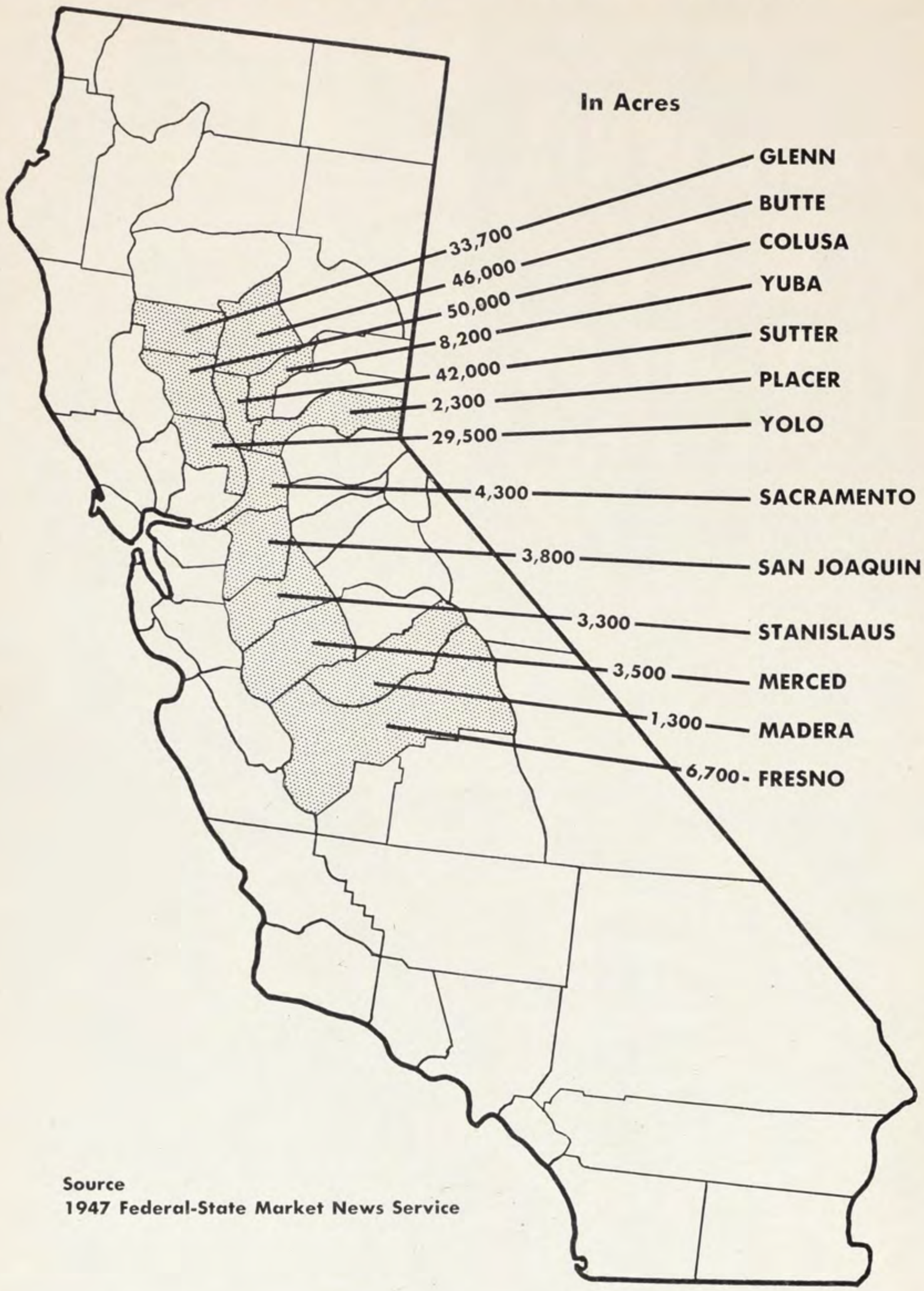
CALIFORNIA RICE PRODUCTION

LOREN L. DAVIS

Circular 163 April, 1950

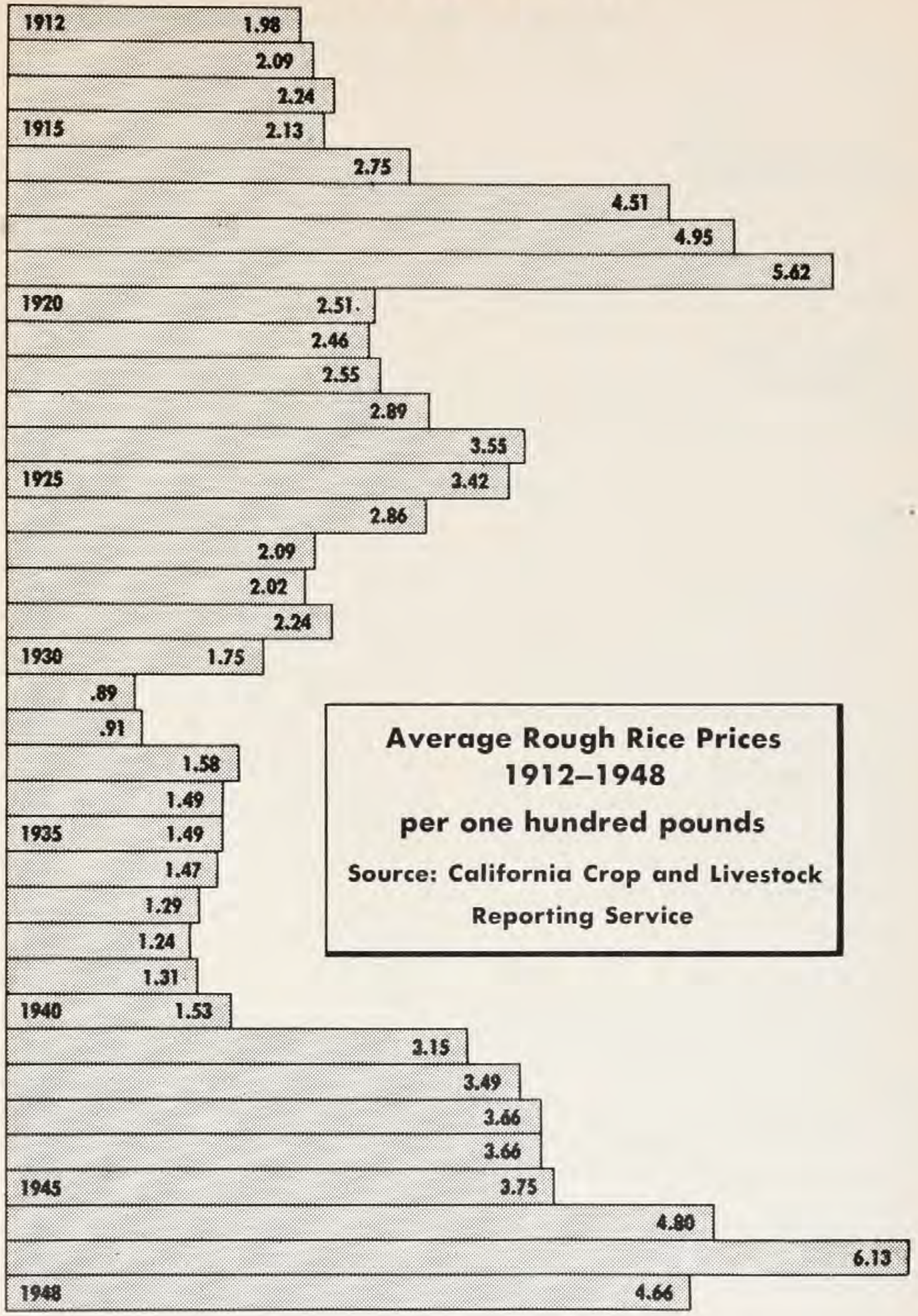


WHERE RICE IS GROWN IN CALIFORNIA . . .



THE AUTHOR, Loren L. Davis, is Extension Specialist in Agronomy. Formerly Associate Agronomist in the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. D. A., and Superintendent of the Biggs Rice Field Station, Biggs, California.

...AND WHAT WAS PAID FOR IT



Average Rough Rice Prices 1912–1948

per one hundred pounds

Source: California Crop and Livestock Reporting Service

COMMERCIAL RICE GROWING in California started in 1912 after it was determined that climatic and soil conditions were suitable for the production of early to midseason maturing rices of the Japanese varieties.

ACREAGE —During 1918–1941, the California rice acreage was maintained between 100,000 and 150,000 acres a year. In 1942, it exceeded 200,000 acres. The highest acreage was in 1949 with 290,000 acres and a total production of 22 million bushels of rough (paddy) rice.

PRICES paid farmers for rough rice have fluctuated widely. They have varied between 89 cents per hundredweight in 1931 and $6.13 in 1947.

ADAPTATION

Soils

Rice is adapted to the heavy soils of the Sacramento and San Joaquin valleys. The impervious subsoil of clay and adobe-clay soils are well suited to rice culture. Such soils require less water to produce a crop; and after draining in the fall they usually crust quickly at the surface. This makes it possible to use heavy equipment in harvesting. Relatively level land is desirable so that the size of checks can be large, thereby increasing the efficiency of large and modern equipment.

Water

Ample irrigation water is essential. Four to ten acre feet is generally required to produce a rice crop, depending on the type of soil and the efficiency of irrigation.

Land requiring over 10 acre feet of water should be fairly well adapted to crops other than rice. This must be considered before using such land in rice production.

Drainage

Good drainage is very necessary in rice production.

Without good surface drainage, fields are slow to dry in the fall. This increases the hazard of crop losses.

Good drainage also permits earlier preparation of the land for seeding, and is also necessary for producing crops in rotation with rice.

Rice is frequently grown for leaching alkali from the soil. Here again, good drainage is essential.

Temperatures

The high temperatures of California's interior valleys are favorable for rice production.

The critical period in the development of rice in relation to temperatures is during the period of heading when pollination of the flowers takes place. This period is between the last half of August and the first half of September, depending upon the seeding date and the varieties grown.

Night temperatures in the forty or low fifty degree range will inhibit pollen tube growth and result in sterility. This causes blighting and low yields.

Delayed maturity, from either late seeding, rich soil, excessive use of fertilizers or late varieties, increases the hazards of loss from sterility caused by low temperatures.

Low temperature is often the limiting factor in the production of rice on some of the heavy soils in the lower Sacramento and San Joaquin valleys.

SEEDBED PREPARATION

Plowing

It is often difficult to prepare a rice seedbed in heavy adobe soils. It is best to spring plow as early as possible after winter rains (fig. 1). Plowing to a depth of 4 to 6 inches is advisable, and adequate for controlling certain weeds.

Disking

Disking, in place of plowing, is sometimes practiced where rice follows beans or other cultivated crops, or where rice follows a cultivated fallow. Disking is usually advisable only on the lighter soils which are often found in the lower Sacramento Valley. Disking is never advisable where rice follows rice in consecutive seasons, or where rice follows an idle fallow previously grown to rice.

Mouldboard plows are generally used in place of disk plows, but disk plows are sometimes better for turning under heavy crops of bur clover or vetch.

Soils Should Be Worked When Dry

Most rice soils work down to a better seedbed when allowed to dry for a week to 10 days after plowing.

Dry soil is essential for killing the roots of certain weeds.

Rice germinates better, produces more rapid growth of seedlings and a heavier crop when the seedbed is worked dry, and there is no rain during seedbed preparation.

Working a moist rice seedbed induces alga and scum development, and increases weed growth of many varieties. It also excludes some of the soil oxygen so necessary in the germination and early development of rice seedlings.

A heavy spike-tooth harrow is most commonly used in preparing the seedbed (fig. 2). Under most conditions, two harrowings followed by one dragging makes a satisfactory seedbed.

A heavy drag is often used where the land is very rough (fig. 3). Some drags are made of heavy wood planks weighted with concrete blocks. Others are made of heavy I-beams.

Avoid Too Smooth a Seedbed

Quite often the seedbed is finely pulverized, and in consequence too smooth. Such a seedbed is bad, especially when seeding on water because both rice seed and seedlings are more subject to drifting. Also, a finely-worked seedbed stimulates the growth of weeds such as sedge, wiregrass, seedling cattail, red stem and waterplantain.

Levees

Levees are constructed by tractor-drawn dikers (figs. 4 and 5).

Dikers are usually made in farm shops. They are 14 to 16 feet wide in front, and 4 feet wide at the back or soil discharge end. The sides are 3 to 4 feet high.

Construction is usually of iron, although some are made of heavy wood planks lined with sheet metal. Many ingenious devices are used to raise and lower the diker.

Power equivalent to 2 large crawler tractors is required to adequately pull a large diker.

A bulldozer attachment on the front of a crawler-type tractor is used for building the ends of levees around the border (fig. 6).

Slope of Land for Levees

Levees are built on a .2 to .3 of a foot fall of the land. On steep sloping land, levees are built on .3 of a foot contour. On very flat land, they are built on .2 of a foot contour.

Wind Levees

It is often desirable to construct wind levees where very level land is used. These are not tied into the border levees, but their function is to restrict wind action on the water.

Leveling

Leveling by landplane reduces the area devoted to levees, and puts the land in better condition for proper irrigation and drainage (fig. 7).

It is not practical to move large quantities of soil with Carryall equipment to reduce the number of levees. Carryall work on rice land can only be justified when used to fill sloughs and small depressions, or to remove small knolls.

Where fills are made, rather late growth of rice and sterility may result.

Where soil is removed, the crop will be very poor unless heavily fertilized, or grown to a covercrop for several seasons.

Irrigation Boxes

Gates or boxes are placed at convenient locations in the levees; preferably along the most accessible side of the field.

There are many types of gates; all made of wood (fig. 8).

Gates restrict the water, and make it possible to regulate and maintain the depth of water.

A gate must be properly constructed and so placed in the levee that it will not wash out. Sacks of dirt placed at the ends of the gate aid in retaining it in the newly constructed levees (fig. 9).

A properly constructed and installed gate or irrigation box appears on page 10.

PICTORIALLY SPEAKING . . .

Preparing a Rice Field Requires—

PLOWING

Fig. 1—Plowing rice stubble land for second year rice. A total width of 28 ft. is being plowed. Heavy equipment and a lot of power are needed to plow this adobe clay land. The old levees have been plowed down. This eliminates plowing inside the levees. New levees will be built with a diker after the seedbed is prepared.

HARROWING

In Preparing the Seedbed A Heavy Spike-Tooth Iron Harrow Is Used

Fig. 2—A heavy spike-tooth iron harrow is commonly used in preparing a rice seedbed. Two harrowings, followed by one dragging, are usually all that are necessary after plowing for a satisfactory seedbed.

DRAGGING

Where the Land Is Very Rough— A Heavy Drag Is Used

Fig. 3—Dragging after harrowing. This drag is made of heavy wood planks weighted with concrete blocks. Some are made of heavy I-beams. Note the seedbed. It is good and about normal for rice. It is dry to the depth plowed. Such a dry seedbed kills old wiregrass roots, lessens the number of aquatic weeds such as sedge and waterplantain, and retards drifting of rice seed and seedlings.

Levees Are Made With Tractor-Drawn Dikers

Fig. 4—Front of diker. Note cable hitch. Hand wheels on side operate worm gear which lowers side wheels for moving diker when not in operation.

And This Is How a Diker Does the Job

Fig. 5—A diker constructing a levee. Side wheels are up. Note that two powerful tractors are needed for pulling this equipment.

The Ends of Levees around the Border Are Built with This Bulldozer Attachment

Fig. 6—Building the ends of levees around the border with a bulldozer attachment. Some bulldozer blades are hydraulically controlled, but the above is operated by a cable from the power take-off attachment.

Leveling by Landplane—
Reduces the Area Devoted to Levees
And
Puts the Land in Better Condition for Proper Irrigation and Drainage

Fig. 7—Land plane used for leveling in rice production. It is excellent for spreading the old levee bases and filling small depressions. Its length may vary from 40 to 60 feet. The blade should be set so that some soil is carried at all times. The above land plane is not preparing the land for rice; such a seedbed would be too smooth.

Irrigation Boxes in Levees

Fig. 8—Irrigation box to control flow and depth of water in the field. Note slots for inserting boards to control depth. Short end of box from depth control boards is placed upstream.

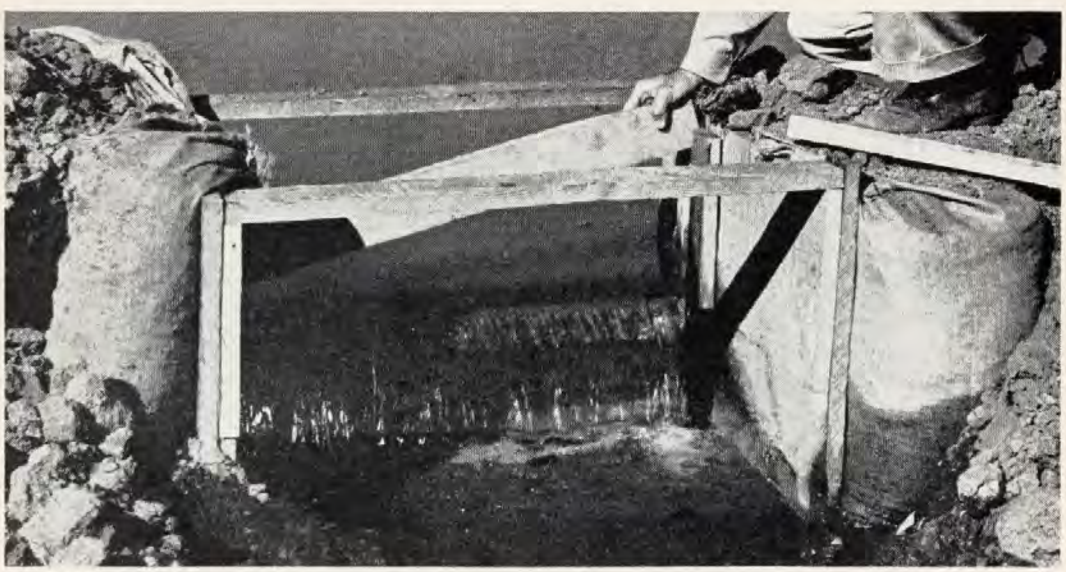


Fig. 9—Irrigation box in the levee with sack of dirt at each corner to prevent box from washing out. Note how boards are inserted for controlling water level.

HERE ARE THE LEADING CALIFORNIA RICE VARIETIES

CHOICE OF VARIETY

The California rice industry has been very fortunate in having so few commercial varieties. From the standpoint of maintaining pure seed, this greatly simplifies the problem of varietal mixtures in harvesting and storage. A small number of varieties greatly increases the efficiency of modern drying, storage and bulk handling equipment, and tends to produce a more uniform milled rice.

A new variety should be put into commercial production only when:

1. It entirely replaces the previously grown variety, or . . .
2. It has commercial advantages over the variety being grown, or . . .
3. It meets demand for a new grain type.

Aside from the yield, which is the most important factor in the choice of a variety, date of maturity, grain type, stiffness of straw and milling quality must be considered. With the recent development of adapted medium grain varieties, the problem of maintaining pure seed and high quality milled rice is going to be difficult due to the short grain types now in commercial production.

Certified Seed—A Good Investment

Use of certified seed grown under the regulations of the California Crop Improvement Association is the only assurance that varieties can be kept pure.

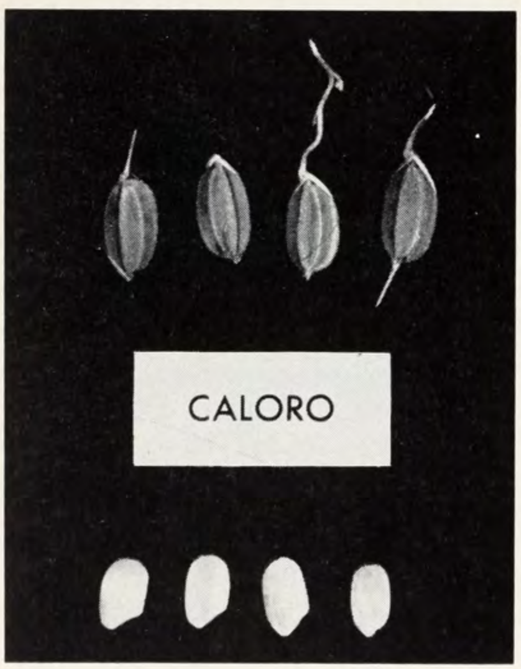
It should be realized that certified seed, even at premium prices, is an excellent investment. The premium paid for such seed is a minor item in the cost of production because pure seed is a very important factor in the production of a profitable crop.

Caloro:

Caloro is the most popular and widely grown (fig. 10). It is well adapted to all rice sections of the Sacramento and San Joaquin valleys. Under a wide range of conditions, its yields are good. It has the desirable characteristic of shortening its growing season when planted late. It has short grain, is partly awned and matures in about 150 to 155 days. Milling quality is only fair. The kernels mostly have white chalky centers, and this leads to an unattractive milled product.

Caloro will continue to be a popular variety in California to supply the demand for short grain type rice.

Fig. 10—Panicle of Caloro, and rough and milled rice. Rice is about twice normal size.

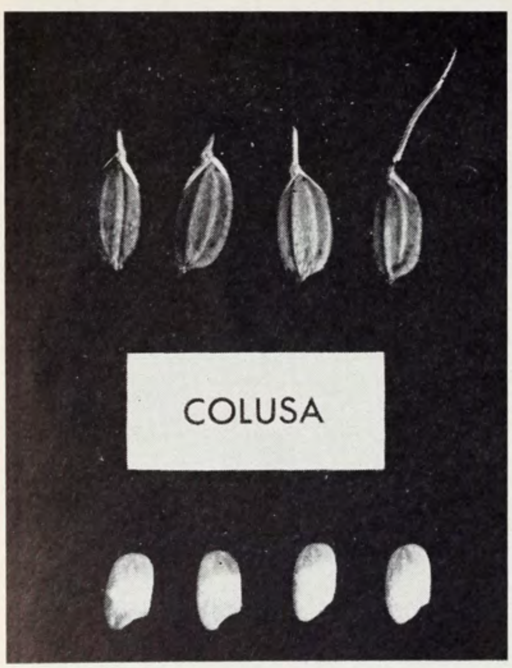


Colusa:

Commonly known as 1600 (fig. 11). It is an early maturing, short grain rice best adapted to new or rich land, or areas of California troubled by sterility due to low, late summer temperatures. It matures in 135 to 140 days. If planted late, it does not shorten its growing period. It does not head or mature uniformly, and lodges badly.

Colusa was grown on about 13 per cent of the California acreage in 1948.

Fig. 11—Panicle of Colusa (1600), and rough and milled rice. Rice is about twice normal size.



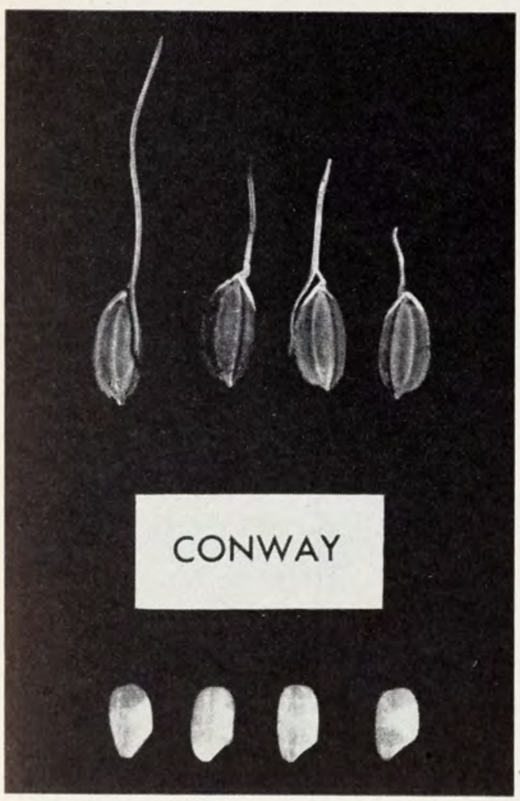
Conway:

A new variety distributed by the Biggs Rice Field Station in 1947 (fig. 12). It was developed from a Japanese variety. The grain type is short, and the maturity is about midway between Caloro and Colusa, or in about 140 to 145 days. It is awnless. The plants are shorter than Caloro or Colusa, and do not lodge as badly as Colusa. The field yields are almost equal to Colusa. The milling quality is good, giving a high head rice yield of relatively attractive milled rice.

Farmers report that Conway is difficult to thresh when directly combined. For this reason, it may not become a popular variety.

About 2,000 acres of Conway was grown in 1948.

Fig. 12—Panicle of Conway, and rough and milled rice. Rice is about twice normal size.



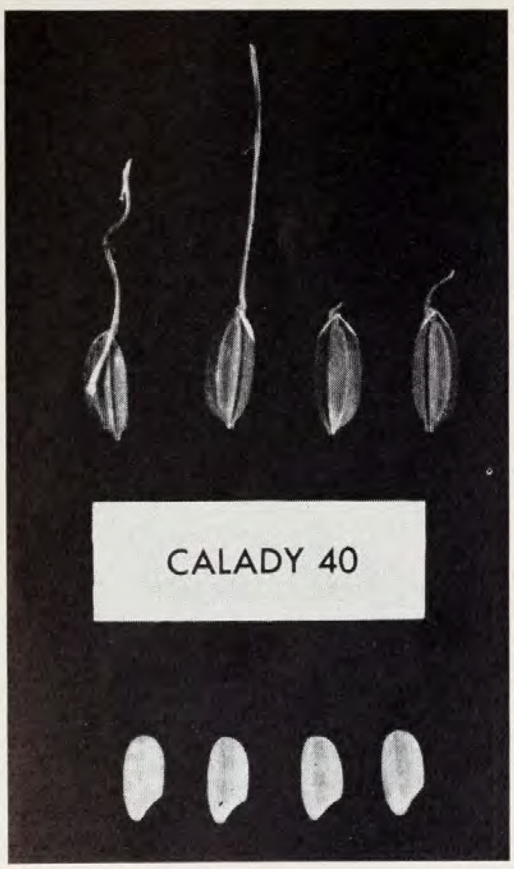
Calady 40:

Developed at the Biggs Rice Field Station from selections made from a commercial field of Calady (fig. 13). It has medium grain of the Blue Rose type. The milling quality is good, and the appearance of the milled rice is attractive. It matures slightly later than Caloro; in about 155 to 160 days. This variety is a very vigorous grower; especially on rich land. It has large coarse stalks and many leaves. It is often difficult to combine due to its excessive vegetative growth.

It seems advisable to limit this variety to sections having high temperatures, soil of average fertility, and where early seeding is possible.

Calady 40 was grown on less than 1,000 acres in 1948.

Fig. 13—Panicle of Calady 40, and rough and milled rice. Rice is about twice normal size.



Calrose:

A new variety developed at the Biggs Rice Field Station (fig. 14). It was first distributed for increase on a small acreage in 1948. It is a medium grain variety of the Blue Rose type, and like Caloro in all plant characteristics except grain length and shape. It requires about the same length of growing season as Caloro. It appears to equal Caloro in field yield. The milling quality is good, and the milled rice has an attractive appearance.

Calrose is expected to be well adapted to all rice growing regions of California, and should become a very popular variety for the production of a Blue Rose type of rice.

Fig. 14—Panicle of Calrose, and rough and milled rice. Rice is about twice normal size.

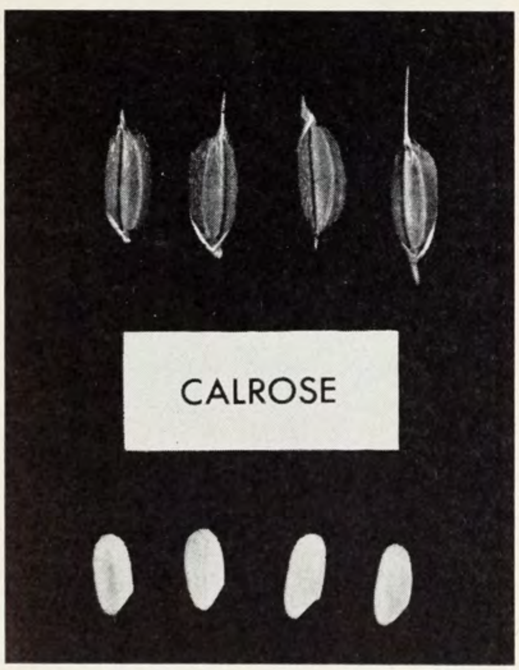


Fig. 15—Rice field ready for seeding by airplane. The above is a well contoured field.

Seeding on the water should follow immediately after flooding a field. (fig. 15).

Nothing is gained in flooding a field and waiting a few days for the water to warm up before seeding.

Most every night, the temperature of the water is lower than the source of the water used for irrigation, therefore there is no gain in delaying seeding to allow the water to warm up.

The water temperatures in the spring, when exposed to sunlight and before the rice emerges, are near the maximum and minimum air temperatures for the day. On days of high wind and low humidity, when evaporation is high, the water temperature may be as much as ten degrees colder than the air temperature. This cooling effect on the water from evaporation is greater at night or during cloudy days than on days of bright sunshine.

Another advantage of seeding immediately after flooding is to reduce the time for wind or wave erosion. When the checks are first filled and the levees are new, they wash out rather rapidly during windy weather, and getting the plants up offers some resistance to wave action.

Seeding by Airplane

It is the usual practice to seed on the water by airplane with pre-soaked seed (see next page and figs. 17 and 18). Only under very special circumstances should the drilling of rice be considered. It might be done on new land of light texture if seeding is early enough to obtain stands without irrigation. The only advantage in drilling is to mature a crop with less lodging, and to allow early seeding before irrigation water is available.

It is never advisable to drill rice on land containing watergrass seed, or where irrigation is necessary for germination.

Some of the advantages of airplane seeding on water are:

1. It is a fast method.
2. Slightly less seed is required.
3. It is not so important to prepare a good seed bed.

Seed Right after Flooding

Allowing the water to stand for several days before seeding gives weeds and grass a head start over the rice. Scum and alga growth also starts and this hinders seedling development.

In some cases during hot weather, much oxygen is lost from the water and poor germination results.

If water is allowed to stand on the soil for several days before seeding, it slacks the soil so completely that the young roots of the germinating seeds have difficulty

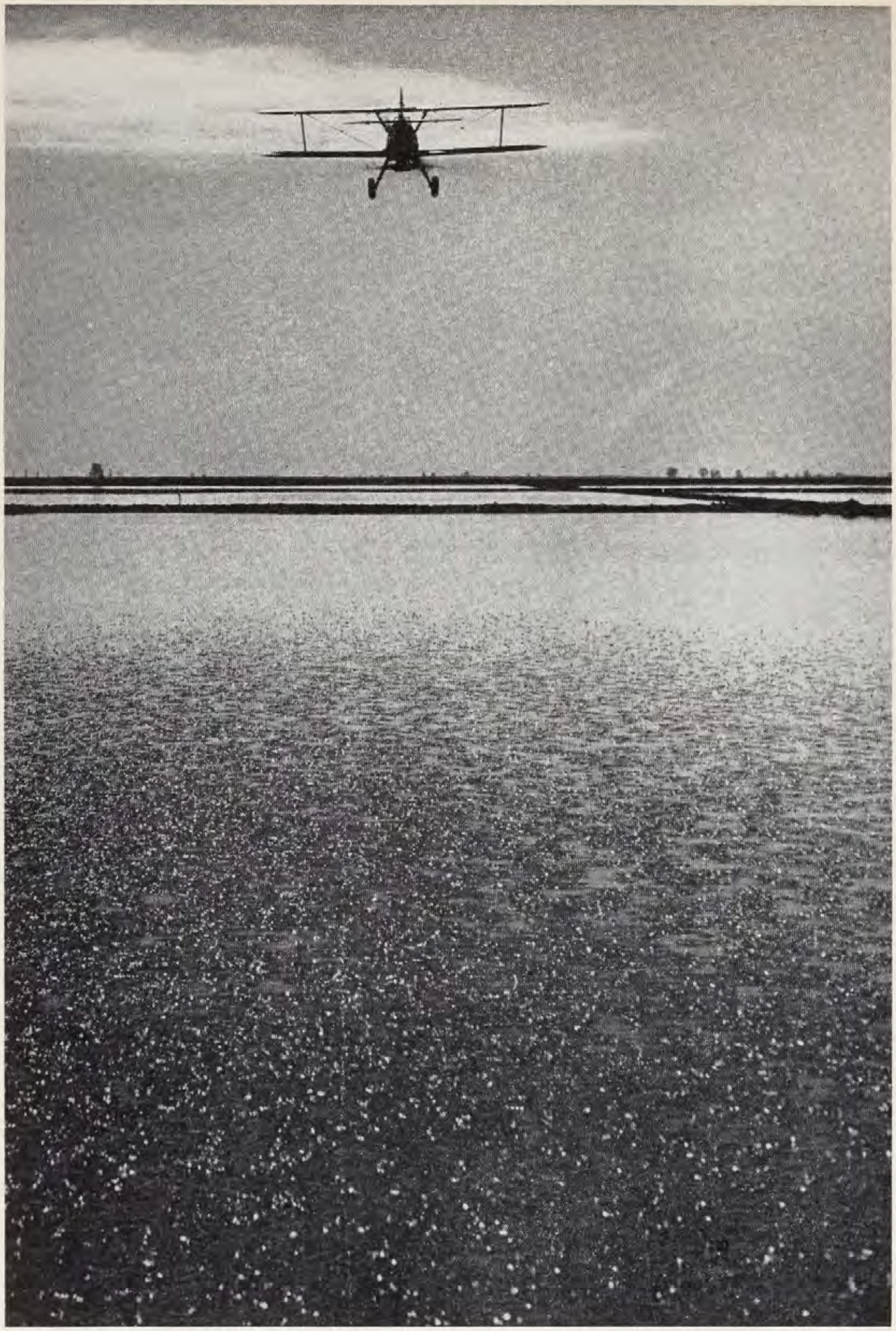


Fig. 16—Airplane "going away" after seeding rice on water. Seed hitting the water is shown in the foreground. The pilot is guided by flagmen at each end of field. Planes fly 20 to 40 feet above water. Spread of seed is from 16 to 20 feet.

in becoming established. In consequence, drifting of the germinated seedlings is severe.

Broadcasting Soaked Seed

Broadcasting soaked seed eliminates seed drift and insures a more uniform stand. Rice seed is soaked in burlap bags which should be sewed rather loosely to allow for expansion of the soaked seed. Soaking tanks are quite common (fig. 19). They are much more convenient to use than are irrigation canals or drainage ditches (fig. 20).

How Long to Soak Seed

Soaking the seed requires between 36 and 48 hours.

Fig. 17—Hopper mounted on truck is used for loading seed into airplane. Hopper is elevated and seed moves into plane by gravity. While plane is seeding, hopper is lowered and filled again. Plane carries from 600 to 900 lbs. of seed on each trip. This amount is enough to seed from 4 to 6 acres on each flight.

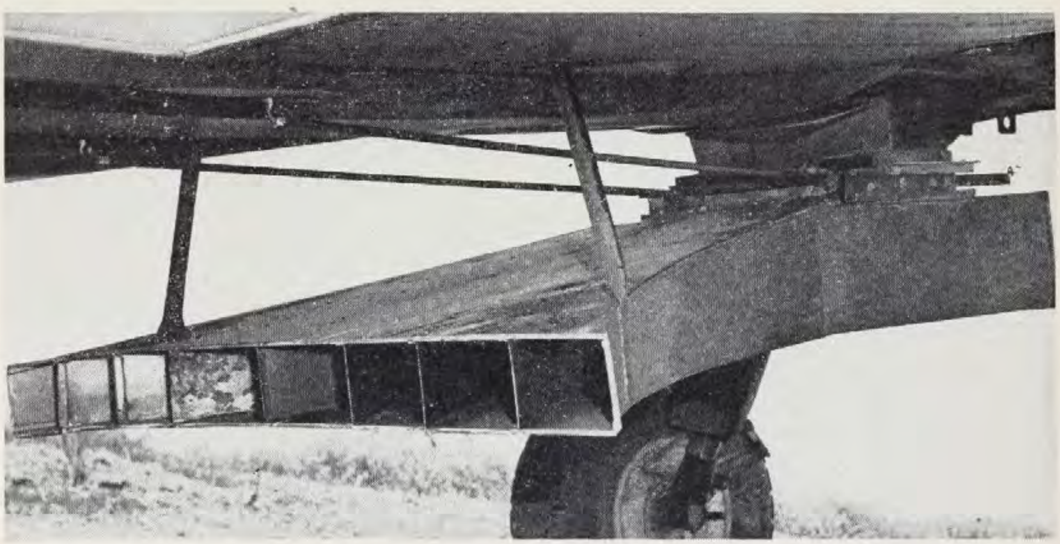


Fig. 18—Broadcast seeding attachment fixed directly beneath airplane seed hopper. A lever in the cockpit operates a sliding door which regulates the flow of rice from hopper to seeder and the rate of seeding. This equipment is also used for fertilizer, and copper sulphate in tadpole shrimp control.

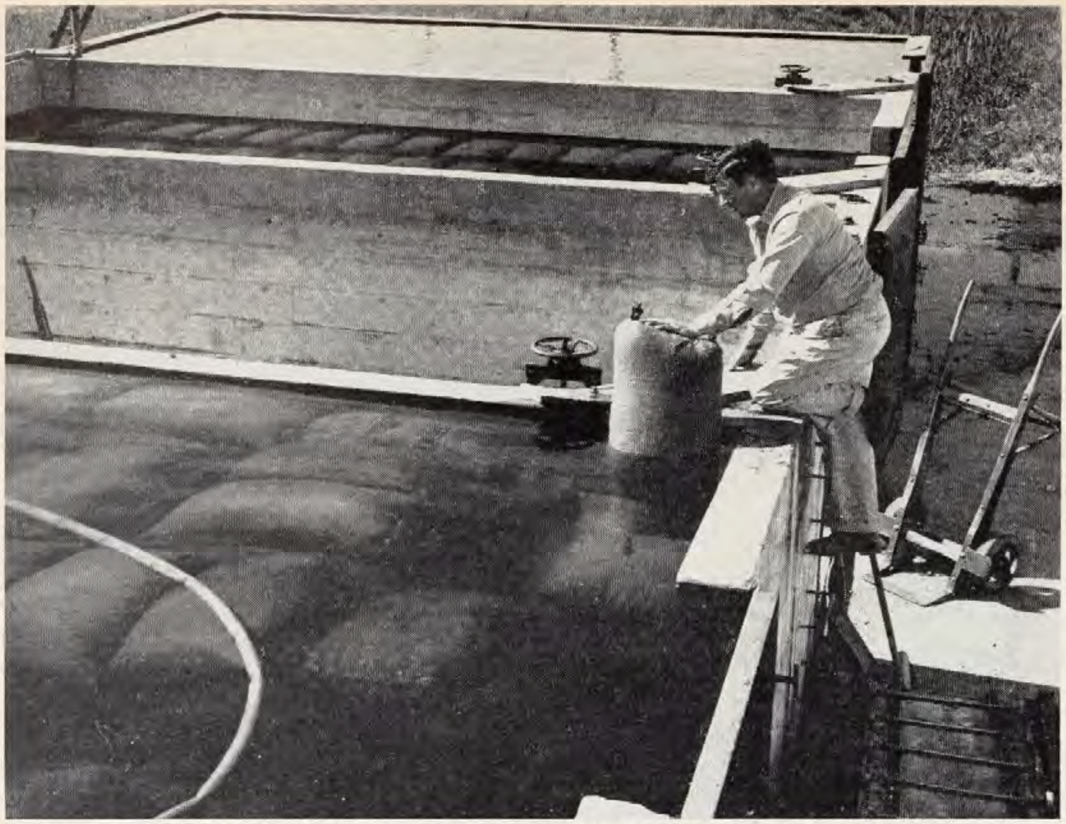


Fig. 19—Concrete vat for soaking rice seed. It is divided into four compartments. Each compartment measures 12 feet wide, 24 feet long, and 5 feet deep; has a capacity of 1,440 cu. ft.; holds about 400 sacks; and has a water-tight door so that it can be filled or drained independently of the other compartments. Rice is soaked from 36 to 48 hours and then drained from 12 to 24 hours before seeding.

Twelve to 24 hours should be allowed for draining the sacks before seeding.

After soaking and draining, the germs should be expanded and perhaps showing through the seed coat. Avoid allowing the sprout to obtain such a length that it will be broken off during seeding.

When to Seed

Rice is seeded in California during April and May. Common practice is to seed as soon after April 1 as weather and soil conditions permit.

April 15 to May 10 is considered the best period for seeding. This enables harvest to begin about October 1 when weather conditions are best suited for the production of high milling quality rice.

Temperatures are often too cold before April 15 to insure a good stand.

Seeding later than May 30 is hazardous because crop losses from fall rains and immaturity are quite high.

Rice seeded on the poorer soils as late as May 30 may mature satisfactorily, but the use of fertilizers or cover crops on rice seeded at this late date is not recommended, and early varieties are usually preferred.

Seeding on a Dry Seedbed

This is the most practical method of seeding small acreages (fig. 21). Seeding dry gives the rice an even start with watergrass and other weeds. Rice lodges less when seeded dry due to better anchorage of the roots.

Fields that are very slow to submerge because of limited water supply are best seeded dry just ahead of the water.

Fig. 20—Rice is sometimes soaked in irrigation or drainage ditches. Sacks are being lifted out of the water by power operated crane. The equipment was made in a farm shop.

Fig. 21—Broadcast seeder, or end-gate seeder, for seeding rice on a dry seedbed. Airplane seeding has replaced this method. But this method is used extensively for broadcasting sulphate of ammonia on dry land after seedbed preparation and just before flooding. A coarse form of sulphate of ammonia is used to obtain a uniform application.

Seeding Rates

The usual seeding rate is 150 pounds per acre, but when seeding by airplane with soaked seed 135 pounds per acre should be ample.

There are many factors affecting the stands other than seeding rate such as depth of water, temperature, scum and weed competition. On old land where tillering or stooling is limited, the use of more seed may be advisable than on new or fertile land. Stands that are too thick show more tendency to lodge. Thick stands, however, head and mature more uniformly than thin stands where stooling is abundant. Thick stands also compete with and control weeds, and this is a very important factor.

Little differences in yield are obtained from seeding rates of 125 to 200 pounds per acre. Some growers are using 125 pounds per acre and getting good results. On level land of average fertility that irrigates well, 140 pounds of soaked seed broadcast by airplane is ample; but for insurance against weather, scum, weeds and uneven land 150 pounds is recommended.

Maintaining Pure Seed

In the production of pure seed, the hazards from mixtures due to airplane seeding must be considered.

Farmers should respect the efforts of a neighbor attempting to maintain pure seed. Arrangements to eliminate mixtures should be made. This may be done by changing the direction of flight when seeding. Pilots should be cautioned about the dangers of mixtures. It may be necessary to broadcast a strip adjoining a field being grown for seed by hand or seeder.

FERTILIZATION

Fertilization of rice is common practice in California except on the most fertile soils, new lands, or where rice follows a heavy legume cover crop, such as bur or Ladino clover.

Except in isolated areas, nitrogen is the only element that gives favorable response.

There is some indication that phosphorus may be needed for rice in the red soils along the eastern edge of the Sacramento Valley.

On the heavy soils in the principal rice growing area of the Sacramento and San Joaquin valleys, nitrogen is the only element that gives profitable response.

Rice, growing on submerged land, takes its nitrogen from the soil in the form of ammonia, therefore, nitrogen should be applied in the ammonia form such as sulphate of ammonia, urea and cyanamid.

Rice does not respond well to nitrate fertilizers when grown under continuous submergence.

Rates of Application

The rate of fertilizer application varies with the fertility of the soil.

On soil of average fertility, that is one capable of producing nearly 35 sacks of rice per acre without fertilizer, 150 pounds of sulfate of ammonia per acre is the proper application.

On land of lower fertility, more fertilizer is needed. Two hundred and fifty pounds of sulfate of ammonia may be profitably used on land producing only 20 sacks of rice or less per acre without fertilizer.

On land producing 45 sacks or more per acre, the desirability of fertilization is doubtful. Fertilizing rich land may delay maturity, increase the possibility of sterility, and result in severe lodging.

When to Fertilize

Application of sulphate of ammonia can be made at any time from seeding and up to 65 days after seeding with equally good results. Fertilization after seeding is done by airplane.

Fertilization at seeding increases the rate of growth and vigor of the young seedlings, and helps in obtaining a good stand. If good stands can be obtained without fertilizer, equally good results can be obtained by applying sulphate of ammonia in the water at any stage of growth up to 65 days after seeding.

It is unnecessary to lower the water when applying sulphate of ammonia. There is apparently no loss of fertilizer from the field through drainage water.

Increases of 800 pounds of rough rice per acre may be expected when 150 pounds of sulphate of ammonia is used on land of average fertility. Using sulphate of ammonia at 150 pounds per acre on land of average fertility does not materially delay the maturity.

Fertilization with sulphate of ammonia on land of high fertility may delay maturity for several days. This would increase the chances of heading during a period of low temperature and result in sterility.

The application of anhydrous ammonia in irrigation water is impractical because of the uneven distribution of nitrogen. The use of soil applicators is being explored, but application by this method must be to a depth where the ammonia will come in contact with the moist soil or it may be lost by volatilization. It is doubtful that this method of nitrogen application will be practical on the rough, heavy adobe soils. It would seem to be a slow and expensive method of fertilizer application on so large a scale as is necessary for rice.

Farmers should be very cautious in trying the liquid fertilizers occasionally placed on the market. They are often impractical to apply, and too expensive.

Farmers should also be careful in using cyanamid on rice. It should be applied on the dry soil before seeding so that the period of toxic effect will be over before the seed germinates. Cyanamid applied in the water after the rice emerges has a very definite burning effect and may be very injurious to the young seedlings. The burning effect is noticeable on rice that is two months old, but it appears to recover without serious injury.

IRRIGATION

Rice tolerates a wide range of irrigation practices which have little effect on the ultimate yield provided ample water is supplied.

There are three functions of water in rice culture as practiced in California. These are to:

1. Supply the plant with water to carry on its normal life processes.
2. Control weeds.
3. Serve as a temperature regulator by maintaining a more uniform temperature for plant growth.

The best growth, yields and quality result from growing rice under continuous submergence. In some parts of the world rice is grown as an upland crop without irrigation, but under such conditions the yields are low and the quality is not equal to that of irrigated rice.

Depth of Water Is Important In Weed Control

Adequate submergence will control some weeds. This is of utmost importance.

Watergrass is the most common weed that is controlled by continuous submergence. For adequate control, the water must be held at a depth which does not allow the grass seedlings to emerge. If the water is lowered for even a short period, watergrass seedlings will emerge, and they are then very difficult to kill.

Control of Watergrass

There are several varieties of watergrass; some are much more difficult to control than others.

The early maturing, small seeded varieties are easy to control. Continual submergence in 3 to 4 inches of water gives almost complete control.

The large seeded varieties, known as white watergrass or Oriental watergrass, are more difficult to control. They must be continuously submerged in 5 to 7 inches of water. Even at this depth a few plants will emerge, but seldom in sufficient number to affect the growth of the rice plant, or the quality of the rough rice.

Period of Control

Eighteen to 20 days submergence is sufficient to control watergrass. After this period, the water can be lowered without increasing the growth of the weed. Where scum is a problem and the water must be lowered to let the rice emerge, watergrass will also find emergence difficult. Under such conditions, control may be achieved with 3 to 4 inches of water.

Uneven Land Must Also Be Considered in Weed Control

In some places the water may be 12 inches deep; in others the soil may be barely covered. Generally, it is better practice to hold water at a depth of 3 to 5 inches on the high spots for partial control of watergrass, and sacrifice stands of rice in deep water.

Lowering Water to Eliminate Drifting

On the lighter soil types, it is sometimes necessary to lower the water to eliminate the drifting of young seedling plants that have become detached from the soil due to water action caused by wind. At this time, watergrass may appear. To lessen the chances of drifting, it is advisable to have a rough seedbed and to seed immediately after flooding.

In the case of very level land, wind levees should be constructed to lessen wind action on the water.

Maintain Depth of Water During the Growing Season

Water should be held continuously at a uniform depth of 5 to 7 inches during the growing season. There is no proof that deep water hastens maturity. Five to 7 inches is ample to give regulation between day and night temperatures necessary to produce maximum development of rice.

Checking Excessive Growth

Where growth is excessive, it is sometimes advisable to drain the water and dry the land. If excessive growth is not checked it may result in a very late crop that will not fill well or mature.

The growth of rice can be checked sufficiently to induce proper maturity by drying the land when the rice has stooled enough to insure a good stand, and before the plants begin to joint. This is usually 60 to 75 days after seeding. The land must be dried to a point where the rice actually suffers from lack of moisture and shows evidence of burning. This requires about three weeks without water, and depends somewhat on the weather and soil type. But drying a field containing average rice growth results in delayed maturity and reduced yields.

DRAINING

Draining at the proper time before harvest is most important.

Land must be dry enough to support harvesting equipment. It is equally important to hold the water on the land long enough for proper maturity of the rice.

There is no fast rule as to the time to drain because soil type, drainage facilities and season all play a part. Some soils dry and crust very quickly after draining; others are very slow to dry. Less time is required to dry the soil for harvest early in the season when temperatures are high and the days longer, than is required later in the fall. Each farmer should know the soil and drainage features of his land to properly judge the time to drain.

Fig. 22—Pull-type combine harvesting swathed rice. The pick-up attachment is used on the side instead of the header attachment with cutter bar and reel. The moisture content of rice harvested in this manner is low enough for storage and makes dehydration unnecessary. Rice is being sacked on the above combine.

A Good Rule on When to Drain

A good rule on when to drain is one of observing the date of first heading, or when approximately one-tenth of the rice heads are emerged, and keeping in mind that crops of average yield will be ready for harvest in about 45 days from the first heading date.

Heavy crops with yields of 50 sacks or better per acre may require as much as 55 days from first heading to maturity.

By keeping the heading date in mind and calculating the date of maturity, it is possible to know when to drain and have the land dry for harvest; that is if the characteristics of the land are known.

Water intake should be discontinued a few days before draining. The water already on the field should be allowed to recede slowly. This lessens lodging and does not overtax the drainage system with excessive water. It also lowers production costs.

HARVESTING

Direct combining and artificial drying is the most common method of harvesting rice in California.

In some cases, the rice is swathed and allowed to dry in the field after which it is threshed with a combine equipped with a pick-up attachment (fig. 22). Rice in the swath usually requires 3 to 6 days to dry sufficiently before storage. The swathing method of harvesting is cheap, but the milling quality is often low and the hazard of crop loss due to rain when the rice is in the swath is considerable.

Types of Combines

Combines vary widely in make, size and type. They range from the small tractor-drawn 6-foot cut type to the mammoth self-propelled 20-foot cut custom built models. Many self-propelled push-type

Fig. 23—Self-propelled combine harvesting rice. The pick-up type reel makes it possible to harvest lodged rice with very little loss. This combine is custom built; mounted on tracks; and has two motors, one for propelling the machine and the other for operating the thresher. Header attachments are hydraulically controlled. Because of the bulk bins, only one man is required to operate this harvester.

models are made in farm shops and have a stationary thresher mounted on tracks. Many of these combines are capable of threshing 1,800 sacks of rice a day.

The self-propelled combine is commonly used (fig. 23). On this type, the cutter bar is mounted in the front which makes it possible to open up the field by making the first cut around the "check," after which the pull-type combine may be used to finish the harvest.

Moisture Content at Harvest Affects Milling Quality

Combining at the proper stage of maturity is important if rice of high milling quality is to be obtained.

Harvesting when the moisture content is between 20 and 27 per cent produces rice of the best milling quality if it has been properly dried. When the moisture content is above 27 per cent it may increase the per cent of chalk and lower the grade of the milled rice. It may also result in a low total mill yield. Rice that is allowed to get below 20 per cent moisture content before harvest may be sufficiently sun-checked to give low mill yields of head rice.

Alternate wetting and drying of rice in the field, either by rain or heavy dew when the moisture content is 17 per cent or less, results in severe sun-checking and very low mill yields. Sun-checking is more pronounced if the temperatures are high.

Under average conditions of heat and humidity, the moisture content of standing rice can be expected to drop about 1 per cent a day in the moisture ranges from 30 to 20 per cent. On days of low humidity, the moisture may drop as much as 3 per cent, and on cool, cloudy days there may be little or no decline in moisture.

Handling the Rough Rice

Bulk handling of rice has become quite general, and the saving in labor is remarkable.

Many types of bulk conveyors or wagons have been improvised to transport the rough rice from the combine to the trucks (figs. 24 and 25). They consist of a large steel bin with sloping sides, and an auger in the bottom leading to an elevator which empties the bin. They are usually mounted on tracks. The auger may be powered by auxiliary motor, or a power take-off from the tractor.

Drying the Rice

Rice must be dried carefully to be of high milling quality. Best results are obtained by not reducing the moisture content more than 3 per cent in any one drying operation. This requires a tempering period which is usually from 12 to 24 hours. Bulk bins are more satisfactory than sacks for tempering. Tempering

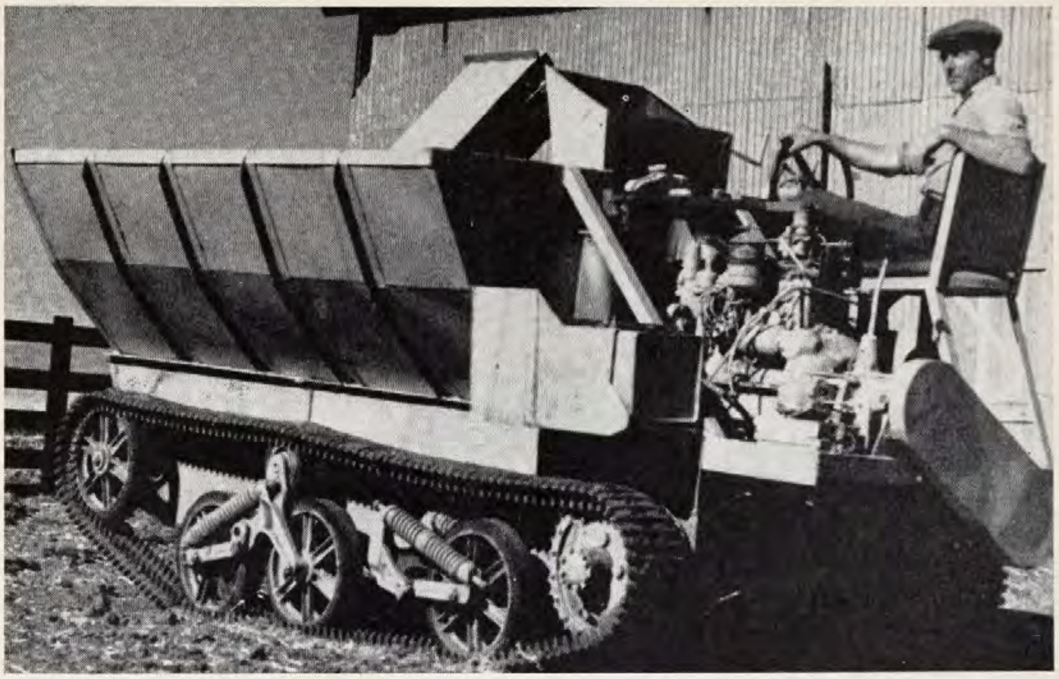


Fig. 24—Self-propelled conveyor bin made from surplus war equipment. It is used for transporting rice from combines in the field to trucks.

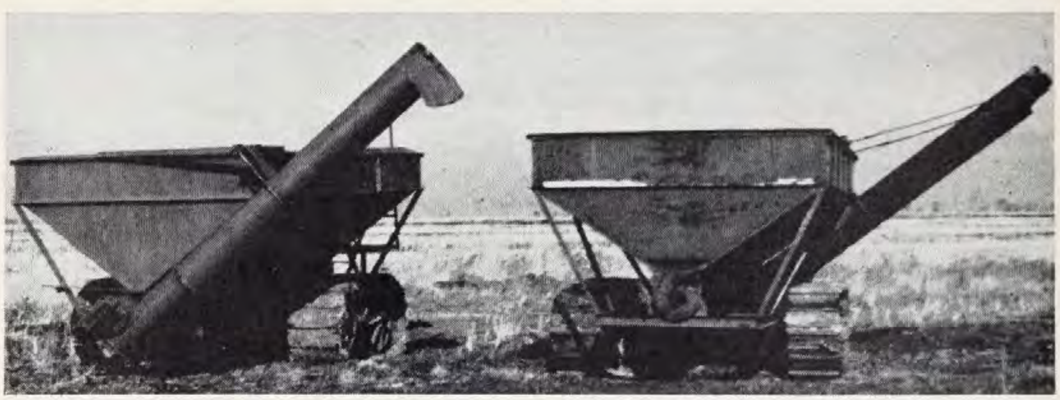


Fig. 25—Most conveyor bins, or tanks, are pulled by tractors. They are usually mounted on tracks, and all types have some auger and elevator arrangement for unloading. The above picture shows fore and aft views.

in bulk bins when the rice has 20 per cent moisture or more requires careful attention to avoid heating; and tempering for more than 48 hours is dangerous because of possible heat damage. Drying temperatures of near 100 degrees Fahrenheit are satisfactory, and usually three runs are required to dry the rice properly if harvesting with 20 to 27 per cent moisture.

Dryers

Rice dryers vary in size from small units for individual operators to large units for commercial drying and cooperatives. Their capacity may vary from 3 to 25 tons per hour. This is on the basis of complete drying: removing 8 to 10 per cent moisture. All are operated on the principle of blowing heated air through columns of rice. Heat may be supplied by butane, natural gas, or oil.

The above types are used for drying bulk rice.

Drying in Sacks

There are a few sack-drying units in operation, but they are not as popular or as efficient as the bulk dryers.

The principle of the sack dryer is to force preheated air through the sacks which are placed over openings in the top of a tunnel, and through which the air is forced by a blower.

Sack dryers have the advantage of being much less expensive to construct, but they are not as convenient to operate because of sack handling; furthermore, no compensation is made for variations in moisture content of rice in different sacks. This may result in lack of uniformity in drying, and the quality of the rough rice may be inferior to rice dried in bulk dryers.

Rice should be dried to 14 per cent moisture content for safe bulk storage. Storage in sacks becomes safe when the moisture content is reduced to 15 per cent.

RICE PRODUCTION COSTS

A rice mangement study conducted by the Agricultural Extension Service in Colusa County for the crop years of 1946 through 1948 provided basic data for the Standard of Input and Cost shown in Table 1. This table is set up on the basis of above average efficiency in production for an owner-operator. It does not represent average costs of production for the industry in California. The principal purpose of the table is to indicate the various operations and cost factors which enter into rice production, and to provide a basis for analysis of individual grower costs.

The Colusa County study showed considerable differences in costs between some growers. The total costs of production per hundredweight in 1948 ranged from about $2.40 to approximately $4.75 for those in the study. Yield per acre was the most important factor affecting costs per hundredweight. During the 3 years of this study, renters averaged somewhat higher total costs per hundredweight than owner-operators.

It should be noted that no allowance was made for sack costs. It must be pointed out, however, that although a large proportion of California's rice crops are bulk handled to the mills, many growers are still using sacks. Also, some renters who bulk handle must provide sacks for the landlords' share of the crop.

Harvesting was assumed to be done entirely with a self-propelled combine, and thus a very low labor cost.

Attention is called to the fact that rates per hour charged for use of tractor and truck in table 1 include overhead costs of interest and depreciation as well as operating costs such as fuel, oil, and repairs. Therefore, investment and depreciation figures near the bottom of the table exclude tractors and trucks. The average investment in improvements and equipment is computed at one half of the original cost.

TABLE 1—A Standard of Inputs and Costs for the Production of Rice in Colusa County with a Yield of 3,500 Pounds Paddy per Acre (1948)* (Bulk Handled). (Prepared by B. B. Burlingame, Extension Specialist in Farm Management.)

	Man Labor	40 H.P. Tractor	1½ T. Truck	Cost per acre	Cost per cwt.
	Hours	Hours	Hours	Dollars	Dollars
Plowing	.8	.8		2.00	
Disking	.5	.5		1.25	
Harrowing	.3	.3		.75	
Other land preparation	.3	.3		.75	
Border work	.8	.4		1.40	
Seeding (plane, soak, haul at 1.2¢)				1.80	
Irrigating and draining	3.0			3.00	
Fertilizing (by plane at 1¢)				1.50	
Bird and weed control (by plane)				1.65	
Miscellaneous	.6	.1	.3	1.20	
Sub-total				15.30	.44
Combining (self-propelled) fuel $1.00	1.2			3.40	.10
Banking out, hauling and miscellaneous	2.5	1.0	1.0	6.75	.19
Drying (contract at 25¢ cwt. wet)				9.45	.27
Total labor and field power				34.90	1.00
Irrigation water				7.00	
Seed, 150 pounds at 8¢				12.00	
Fertilizer (150 lbs. ammonium sulfate at 3½¢)				5.25	
Miscellaneous material and border boxes				1.25	
Total material costs				25.50	.73
General expense				3.02	
County taxes				3.00	
Machinery repairs (excluding tractors and trucks)				4.00	
Insurance and miscellaneous cash costs				1.00	
Total cash overhead				11.02	.31
Total current cash costs				71.42	2.04
Depreciation (excluding tractors and trucks)				4.80	.14
Interest on average investment at 5%; land, $125.00; improvements and equipment, $27.00 (excluding tractors and trucks)				7.60	.22
Total current costs				83.82	2.40
Overhead costs for idle year, pro rata				6.00	.17
Total costs of production excluding management				89.82	2.57

* Based on owner-operated farm. Not included in costs are management, storage and freight. Rates per hour used in computing labor costs are as follows: man-preharvest, $1.00; combine operator, $2,00; other harvesting, $1.50; tractor, $1.50; truck, $1.50.

CROPS IN ROTATION WITH RICE

The heavier soils on which rice is grown are not well suited to the production of many crops.

Ladino clover, grown for both seed and pasture, is fairly well adapted to heavy adobe soil.

Beans grow reasonably well on most heavy soils, but preparation of a seedbed and maintaining moisture for germination is difficult. Stands are often poor. If good stands are obtained, beans usually do well without irrigation, or by subirrigation from lateral ditches.

Wheat is better adapted to heavy adobe soils than is barley. During seasons of moderate rainfall good wheat crops are often produced, but during wet winters crops may be very poor.

On the lighter soils, many crops grow well in a rotation with rice. Wheat, barley, beans and milo are the most common crops grown in rotation with rice.

A rotation often followed is rice, beans, wheat, beans and again to rice. Beans follow rice in the spring after harvest; fall or winter sown wheat follows the bean crop; and beans follow the wheat crop in the summer after wheat is harvested. After the beans are harvested, rice is again seeded the following spring. This rotation is often altered depending on the season, soil condition, or prices of farm products.

Choose a Profitable Rotation Crop

Economy in production must be considered when growing crops on heavy adobe soils. Such soils are mostly difficult and expensive to cultivate. Yields are generally only fair to poor. During periods of high prices many crops may be profitably grown, but in periods of low prices only a few may prove profitable. It is good farming practice to grow other crops in rotation with rice on soils where it is reasonably profitable to do so.

Does Rice Growing Harm The Soil?

The growing of rice does not appear to have a detrimental effect on the soil, and other crops seem to do well following a rice crop. If drainage is good, rice production may benefit alkali soils.

Rice is a good crop for controlling certain weeds, such as morning glory. On the other hand, watergrass may increase by growing rice and become a problem in the growing of irrigated row crops.

WEEDS

Weeds are a problem in California rice production. Plants inhabiting wet places find conditions in the rice fields ideal for their development. Most of the rice weeds have characteristic weed habits, which include hardiness and abundant seed production and shattering. This makes them difficult to control or eradicate.

How Weeds Get into Rice Fields

Weeds may be introduced into rice fields in five ways. These are by:

1. Sowing weed seeds with rice seed.
2. Irrigation water.
3. Birds and animals.
4. Wind.
5. Transferring equipment from field to field.

Weeds are well established throughout the California rice producing area. The problem is not only how to prevent their distribution, but how to control or eradicate them.

These Are the Worst Weeds Found in California Rice Fields

Barnyardgrasses (*Echinochloa crus-galli* and varieties), known in California as watergrasses, are the most troublesome (figs. 26, 27 and 28). There are several types; some bearded and others beardless. These are annual grasses that differ considerably in date of maturity, height, size of stems, heads, and seeds. Watergrass is controlled by continuous submergence; previously described under "Irrigation."

Cattails (*Typha latifolia*) grow in sloughs and drainage ditches, on poorly drained land, and in rice fields (fig. 29). The cattail is a perennial. It spreads by seeds and rootstocks. The cylindrical head of the cattail, ranging in length from 6 to 12 inches, is borne at the end of a round stalk. Each head contains thousands of seeds. These are readily spread by wind and water.

Spike Rush (*Eleocharis palustris*), often called wiregrass, grows on poorly drained land, in shallow ditches, and on field levees (fig. 30). It establishes itself in rice fields in the corners of the checks and in places where cultivation and drainage are poor. It is a leafless perennial plant. It produces seeds at the tapering end of a single round stem. The stems vary in diameter from one-sixteenth to one-eighth of an inch. The spike rush spreads by underground rootstock. It will completely crowd out a good stand of rice, and crops cannot grow where spike rush is well established.

Waterplantain (*Alisma plantago*), often referred to as waterlily in California, was confined for several years to the banks and edges of irrigation ditches, but of late it has been increasing in rice fields (fig. 31). It emerges through water as well as, or better than, rice; therefore, it cannot be controlled by continuous submergence. The seeds of waterplantain are reddish brown in color. The seeds are reported to remain dormant for years and then germinate under suitable environmental conditions. Waterplantain appears to germinate at lower temperatures than does rice. It is often present in large quantities in the intake checks where the cold water enters and the stands of rice are often poor.

Pictures of the worst weeds found in California rice fields appear on the following pages

Burhead (*Echinodorus cordifolius*) is frequently abundant in rice fields and shallow ditches (fig. 32). It resembles the waterplantain; but the leaves are usually larger, the seed stalks are sturdier, and the seed cluster is similar to a bur. Burhead will emerge through deep water. It is most abundant in areas where the rice stands are thin, or in the intake checks where the water is cold. It is spread by seeds. It is easily controlled by spraying with 2,4-D.

Arrowhead (*Sagittaria* species) commonly known as arrowhead lily, is a perennial (fig. 33). It is present to a larger extent in the rice fields on the west side of the Sacramento River than on the east side. During recent years, it has been spreading in the rice fields. Like waterplantain, it makes a better growth in low places in the fields where the stands of rice are likely to be thin. It is usually rather thick along the edges of sloughs, and in deep water. Arrowhead is easily identified because the leaves are shaped like arrows. It is spread by seed and underground tubers.

Sprangletop (*Leptochloa fascicularis*), known in California as raygrass, grows well on low land (fig. 34). It grows to a height of 2 or 3 feet and stools heavily. Its fine stems terminate in a panicle. It matures seed from June 20 to October 1. The seeds are very small and are seldom, if ever, found in threshed rice.

After Sprangletop germinates it will stretch through the water more quickly than rice, but it does not appear to germinate readily under water.

Umbrella Plants. Three species of umbrella plants (*Cyperus*), commonly known as sedges, grow in rice fields. The perennial forms grow on the levees and ditch banks, and on poorly drained abandoned land. These forms are not troublesome on well-drained properly cultivated land. The perennial forms enter the checks on poorly prepared seedbeds, but improved drainage and good cultivation will rid the fields of them. The annual form (*Cyperus difformis*) is most abundant in the rice fields (fig. 35). It does not make its appearance until the land has been submerged for some time. It appears in abundance where stands of rice are thin; and sometimes in good stands. The plants grow from 6 to 18 inches high. A thick stand of umbrella plants checks the growth of rice.

Redstem (*Ammannia coccinea*) is found in shallow drainage ditches and along sloughs (fig. 36). It is often present in rice fields, especially where stands are thin. The plants consist of a single stalk, and the flowers are borne at the axils of the leaves. When mature, the entire plant above the ground is red in color. The seeds are contained in a round capsule which is about the size of a small pea. These capsules are often present in the threshed rice; if green, they may interfere with drying. The base of the stem under water is covered with a white spongelike structure.

Red Rice (fig. 37), also known as Italian red rice, is found in California rice fields. It is similar in appearance to normal rice except for the long awns on the kernels, but its red-colored seed is its outstanding characteristic. It matures earlier than the cultivated rice, and has a longer grain. Its growth resembles that of the commercial rice varieties, but the seed shatters more readily. Red rice lowers the commercial value of the crop, therefore seed rice containing red rice should not be sown.

Jointgrass (*Paspalum distichum*) is a perennial weed pest (fig. 38). It is found in irrigation ditches, and often spreads into the rice checks. It is a creeping grass which spreads rapidly by rooting at the joints or nodes. Runners from this grass may extend from the levees into a rice check for 25 feet or more, and it will grow on submerged land. It is difficult to eradicate because it is able to withstand both drought and water. Jointgrass is very troublesome in irrigation ditches because of the dense growth which partially dams up the ditches unless they are frequently cleaned. It is spread by seed and sections of plants that may be carried by equipment, or that may float in the water.

Water Hyssop (*Bacopa rotundifolia*) is an annual plant (fig. 39). It looks very much like watercress. It is often quite thick in thin stands of rice, and under such conditions appears to retard the development of the rice plants. This weed, however, blooms early in the season. When the water warms up, the weed usually dies and the plants rot and disappear. Water hyssop does not appear to be a serious weed pest except that it may check the growth of rice early in the season.

Bulrush (*Scirpus fluviatilis*) looks very much like nutgrass and spreads by seed and tuber-bearing stolons (fig. 40). A new bulrush (*Scirpus mucronatus*) has recently been observed (fig. 41). It has a triangular stem resembling a sedge plant. It grows about 2 feet high, and develops very rapidly early in the season. It is very easily observed.

SO THAT YOU MAY KNOW THEM

Fig. 26—Variety of Barnyard or Watergrass (Echinochloa crusgalli).

Fig. 27—Variety of Barnyard or Watergrass (Echinochloa crusgalli).

Fig. 28—Head types of varieties of Barnyard or Watergrass (Echinochloa crusgalli).

Fig. 29—Cattail (Typha latifolia).

Fig. 30—Spike Rush (Eleocharis palustris).

Fig. 31—Waterplantain (Alisma plantago).

Fig. 32—Burhead (Echinodorus cordifolius).

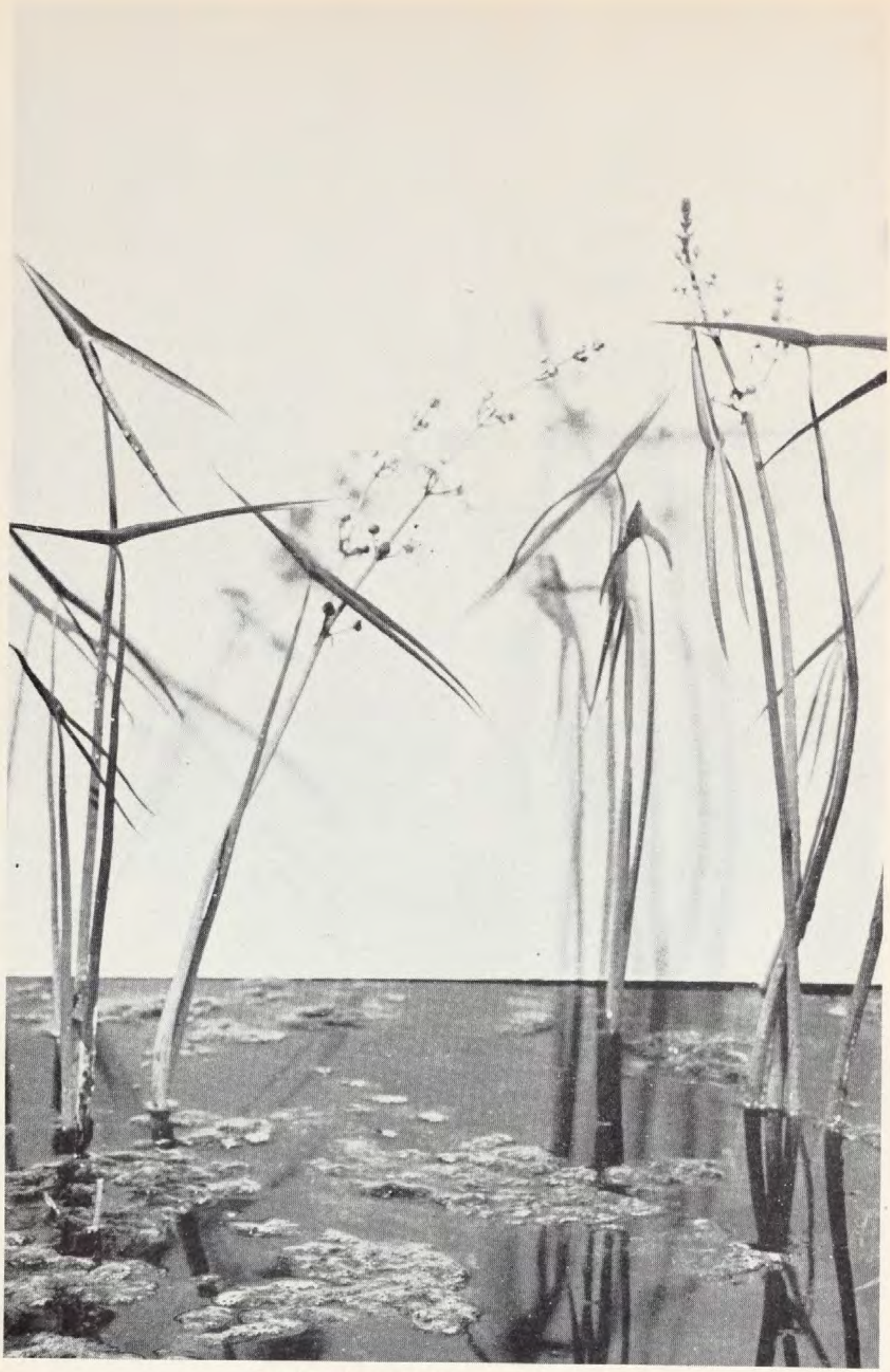


Fig. 33—Arrowhead (Sagittaria species).

Fig. 34—Sprangletop (Leptochloa fascicularis).

Fig. 35—Umbrella Plant (Cyperus difformis).

Fig. 36—Redstem (Ammannia coccinea).

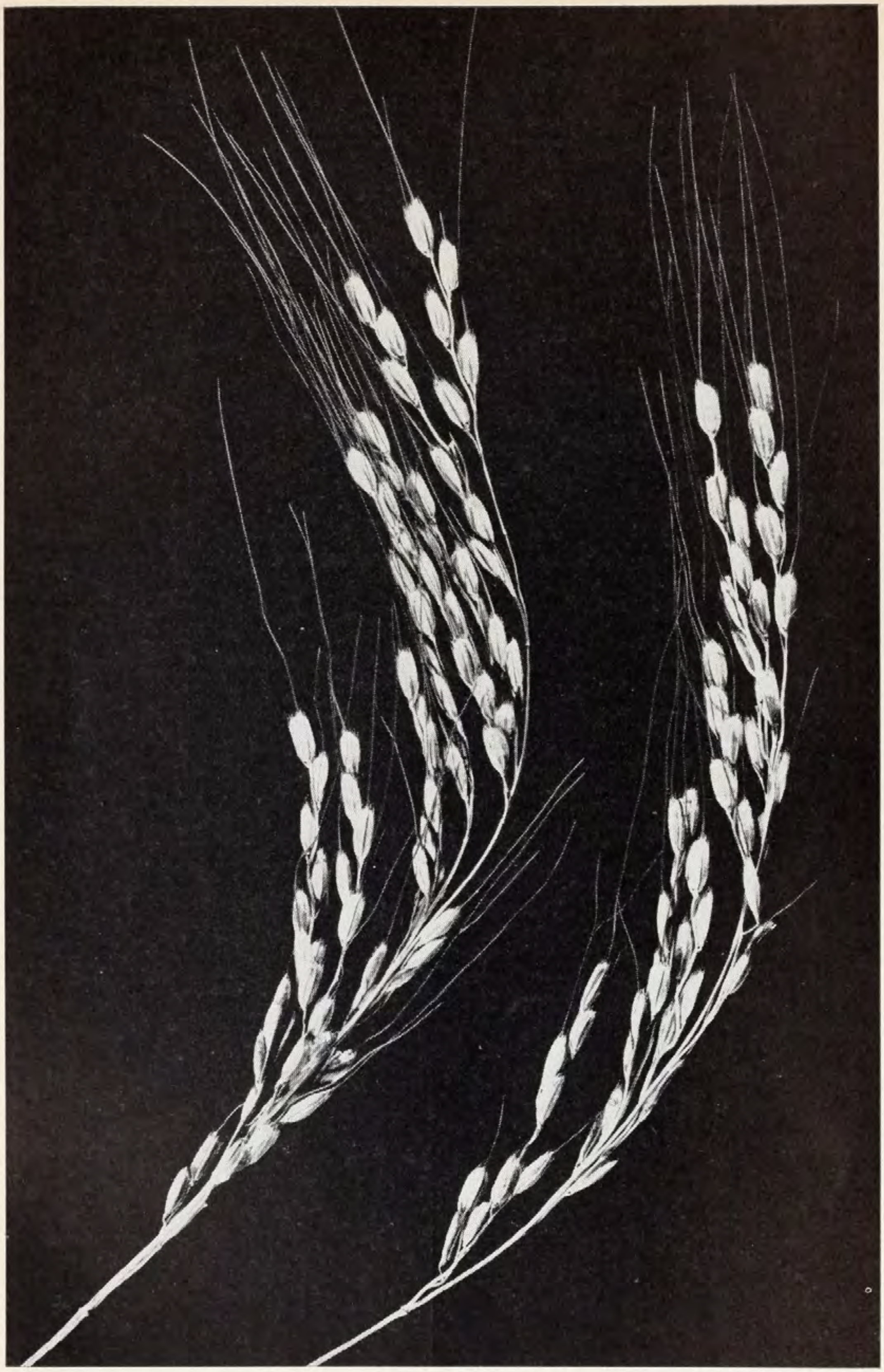


Fig. 37—Red Rice. Note length of awns.

Fig. 38—Jointgrass (Paspalum distichum).

Fig. 39—Water Hyssop (Bacopa rotundifolia).

Fig. 40—Bulrush (Scirpus fluviatilis).

Fig. 41—Rough-seed Bulrush (Scirpus mucronatus).

The control of weeds by irrigation and cultivation has been partially discussed under the heading "Irrigation."

Watergrass and sprangletop are the only weeds mentioned above that can be controlled by continuous submergence; while deep water may have a tendency to reduce the population of certain other weeds such as the sedges, redstem and jointgrass.

A rough seedbed will reduce the population of sedge, seedling cattail, redstem, waterplantain and burhead. Red rice can only be controlled by using rice seed that is free of red rice. Thorough plowing followed by complete drying before seeding will control old stands of cattail, spike rush and jointgrass.

Using 2,4-D for Weed Control

Spraying 2,4-D by airplane (and sometimes by helicopter) to control weeds in rice is common practice (figs. 42 and 43). A good control is usually obtained on arrowhead, waterplantain, bulrush, redstem, and burhead (figs. 44 and 45).

Fig. 42—Spraying 2,4-D by airplane. The 30-foot boom under wing has 30 nozzles. The shut-off is at the nozzle and not on the line. This lessens the danger of spreading the spray on adjacent crops when making the turns. Planes fly at a height of 8 to 10 feet and carry 75 to 100 gallons of spray on each trip.

Fig. 43—Helicopters are sometimes used to spray 2,4-D. They can maneuver in close places and need less space to refill. But they lack carrying capacity. Helicopters should have a place in spraying irrigation ditches, ditch banks and drain ditches.

Before Spraying a Rice Field . . .

Fig. 44—Arrowhead in rice field about 30 days after seeding.

. . . And the Same Field after Spraying

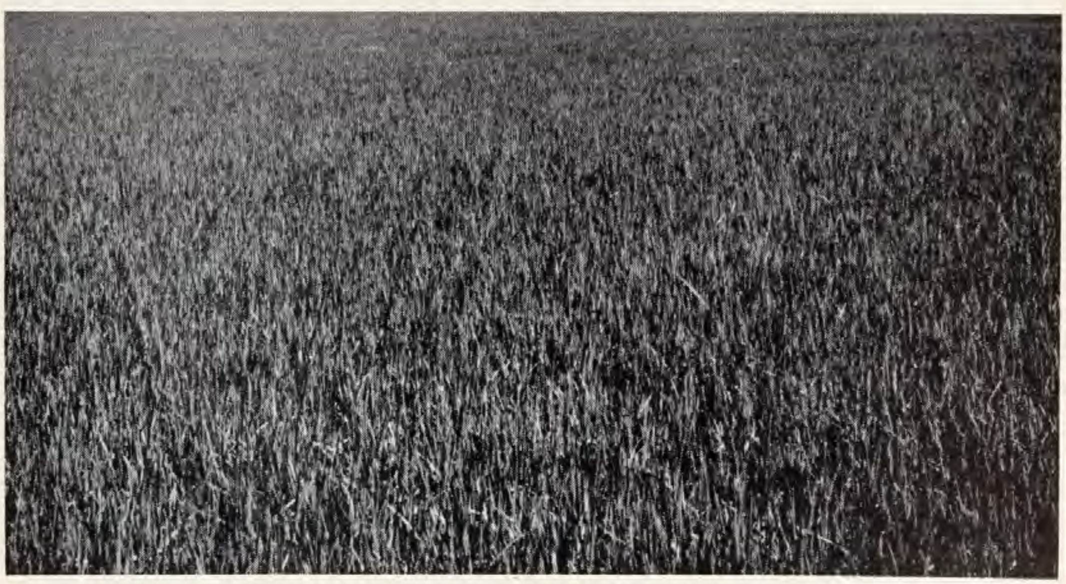


Fig. 45—The same rice field 3 weeks after spraying with 2,4-D.

In some cases, the sedges, cattail, spike rush and water hyssop are partially controlled by 2,4-D.

Watergrass, red rice, sprangletop and jointgrass are not affected by 2,4-D spray.

Rate of Application

The recommendation is to use sodium or amine salt at a rate equivalent to $1\frac{1}{4}$ to $1\frac{1}{2}$ pounds of 2,4-D acid per acre. Since all spraying is done by airplane, the total volume of material on a per acre basis must necessarily be low. Ten to 15 gallons per acre of liquid is usually adequate to assure good uniform coverage.

The sodium or amine salts of 2,4-D are recommended for spraying rice because they adequately control the weeds and are not as dangerous to adjacent crops as are the ester formulations of 2,4-D.

When to Spray

The best time to spray is after the rice is through the water and well established. This will be from 6 to 8 weeks after seeding. At this time, most of the weeds are through the water and sufficiently exposed to the spray. The water can be lowered slightly to expose a greater portion of the weeds, but the rice field should not be drained during the time of spraying.

Rice should not be sprayed when it is approaching the heading stage.

Injury from 2,4-D

There have been some cases of injury to rice in the use of 2,4-D (fig. 46).

In some cases, only occasional plants were affected; in others the injury was severe and resulted in greatly reduced yields.

No explanation has yet been found to account for the severe injury to occasional fields since all recommendations as to rates and time of application appear to have been followed. More reasearch will be necessary to account for the occasional severe injury to rice from the use of 2,4-D.

Fig. 46—The five rice plants on the left show severe injury from 2,4-D. The three plants on the right are normal. Note the short stunted growth, twisted plants, and short stubby root growth of the damaged rice.

Rice Plant Reaction to 2,4-D

Rice plants sprayed with 2,4-D show certain plant characteristics such as a reduction in the fibrous root system and a stimulation of secondary large roots. Rice may show a temporary yellowing after spraying, followed by a dark green color that persists throughout the remainder of the growing season. Sprayed rice has a tendency to be slightly later in maturity.

Detecting Injury from Spraying

Evidence of severe injury cannot be detected until the rice heads form. At this time, the heads are small, the plants short, the leaf sheath is tightly wrapped around the head which makes emergence of the head difficult, and there is an increase in the amount of sterility. In severe cases the rice may never head.

Branching at the nodes, which results in many small immature and deformed heads on each plant, is common.

DISEASES

At the present time there are no rice diseases in California that are of economic importance.

Stem rot (*Leptosphaeria salvinii* catt.) has been present in California rice crops for several years, but has caused no damage. However, this is a serious disease in the southern United States and many other rice-producing countries of the world.

Black chaff disease is always present to some degree. In some years it is more prevalent than others, and appears to be worse in late seasons or on late maturing crops. In some cases, only the hulls are blackened; in others, the discoloration may be on the kernel. This results in a blackened surface and an immature chalky kernel. The organisms causing this condition in other crops have been studied and found to be largely *Fusarium* and *Alternaria;* but the organism causing this disease on rice in California has not been determined. There are no known control measures for black chaff disease, and no resistant varieties have been found up to the time of this publication going to press.

INSECTS AND OTHER PESTS

California rice fields are practically free of insect pests. None of the insects of major importance that injure rice in Louisiana, Arkansas and Texas have been found in California.

Grasshoppers

Grasshoppers will occasionally feed on the leaves and culms of rice, and an occasional rice culm may be eaten off and result in blighted heads. This damage is of no economic importance.

Water Boatman

The water boatman (*Corixa* sp.) has been known to deposit its eggs so numerously on the leaves of young plants that they cannot emerge through the water,

Fig. 47—Water Scavenger Beetle (Hydrous triangularis).

Fig. 48—Water Scavenger Beetle larvae. Upper; lateral. Lower; dorsal.

and they die. This occurs on land that remains wet during the fallow season. Low, swampy areas that are put to rice are sometimes troubled with this insect.

Water Scavenger Beetle

The larva of the water scavenger beetle (*Hydrous triangularis*) sometimes causes damage to rice stands by dislodging the young seedlings, or by cutting the roots which permits the plants to float to the surface of the water.

The adult of this larva is the large, black, hard-shell beetle so commonly seen in the water immediately after a field is submerged (fig. 47). The females deposit their eggs in a silk-like case. This case may float free or be attached to objects in the water. The larva appear to feed on decaying vegetable matter in the water, alga, and other water insects. The dislodging of the young rice plants and cutting of the roots seems incidental to the feeding habits of the larva. There is no indication that the larva feed on the green plants.

The adult larva is about 3 inches long, has strong mouth parts, an apparent segmented abdomen and three pairs of legs (fig. 48). It has been confused with the tadpole shrimp, but there is no resemblance.

No control for this larva has been found beyond draining the field. Bluestone (copper sulphate) has no effect.

Tadpole Shrimp

The tadpole shrimp (*Apus oryzaphagus* and *A. biggsi*) has caused more concern than any pest found in California rice fields (fig. 49). It is not an insect, but belongs to the family Crustacea.

The first outbreak of tadpole shrimp occurred in 1946 over a large area in Butte and Sutter counties. Since that time, it has spread over an increasing area and may be expected to extend to the entire rice-producing areas of California.

Damage from Tadpole Shrimp

Damage is threefold:

1. Chewing of leaves, stems, and roots of the very young rice plants before they emerge through the water.

2. Digging in the muddy silt and dislodging the plants which float to the surface.

3. Keeping the water very muddy which excludes light and results in weakened plants.

Tadpole shrimps hatch from eggs laid in previous years. The eggs hatch about 5 to 7 days after the land is submerged; and within 10 to 14 days after submergence the shrimps are fully matured. At maturity they become extremely active on the soil surface, chewing at the base of the plants and making the water muddy. At this time the rice seedlings are very susceptible to damage.

The shrimps begin to deposit eggs about 10 days after hatching. They continue to do so for several weeks.

The adults begin to diminish in number after 4 or 5 weeks. This is probably their normal life span.

Tadpole shrimps may be distributed over an entire field, or be confined to only a few "checks." It is quite common to find them confined to the lower "checks," or to low areas in the field.

Control of Tadpole Shrimp

Control is simple and effective. Apply copper sulphate (bluestone) at a rate of 10 pounds per acre by airplane as soon as the shrimps appear. This will be about two weeks after the land is submerged. The granular type of copper sulphate is more suitable for broadcasting by airplane because a more even distribution is possible. The dust or coarse ground copper sulphate is difficult to spread.

Fig. 49—Tadpole Shrimp (Apus biggsi). Left; dorsal. Right; ventral.

Tadpole shrimps are killed within 48 hours after treatment. The rate of kill depends somewhat on the depth of water held. The kill is quicker in shallow water.

Some measure of control is obtained by placing sacks of copper sulphate in the check boxes in the field. More material is required in this method.

The copper sulphate will often follow the water current around the levee or through the end of a "check" and will not diffuse sufficiently through a field to give adequate control. Staggering the irrigation boxes helps to diffuse the material and aids in control.

Blackbirds

These birds may cause considerable damage in the fall when rice is in the "milk" stage. The damage has the appearance of straighthead, but on close examination injury to the glumes can be detected, and there is evidence of "milk" on the blank kernels.

Shooting during the early morning and evening when the birds usually feed is helpful in keeping them away.

Ducks

Wild ducks may feed in rice fields and cause serious damage. They are readily attracted to fields containing areas of open water. It is common practice to herd the ducks by airplane, but this is not a solution to the problem. The establishment of adequate feeding grounds, either by growing crops or hand feeding, would greatly assist in reducing duck damage.

ACKNOWLEDGMENT

The assistance rendered by Jenkin W. Jones, Principal Agronomist, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. D. A., during preparation of the manuscript is gratefully acknowledged; and thanks are extended to F. Hal Higgins for making three of the photographs available.

Coöperative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture coöperating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. J. Earl Coke, Director, California Agricultural Extension Service.

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49 WAYS TO SOLVE A PROBLEM
. . . FARM ADVISORS

located in 49 California counties and in these towns:

Alturas
Auburn
Bakersfield
Colusa
Cowell
Eureka
El Centro
Fairfield
Fresno
Grass Valley
Half Moon Bay
Hanford
Hayward
Hollister
Kelseyville
Los Angeles
Madera
Marysville
Merced
Modesto
Napa
Orland
Oroville
Placerville
Quincy
Red Bluff
Redding
Riverside
Sacramento
Salinas
San Bernardino
San Diego
San Jose
San Luis Obispo
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Santa Barbara
Santa Cruz
Santa Rosa
Sonora
Stockton
Susanville
Ukiah
Ventura
Visalia
Weaverville
Woodland
Yreka
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