The Irrigation and Culture of Rice

C. Roy Adair and Kyle Engler

Upland rice, which is not irrigated, and paddy, or irrigated, rice require different varieties and different cultural methods.

All of the commercial rice in the United States is grown under controlled irrigation. Several systems of controlled or uncontrolled irrigation are used in various countries to supply the water needed for the development of the rice plant.

Upland rice is grown in areas where rainfall is heavy during the growing season. Much of the rice grown in Central America and South America and in many countries in Asia is produced under upland conditions. Upland rice also is grown for home use in small fields, totaling fewer than 3,000 acres, in the Southeastern States.

A limited acreage of “providence” rice is grown in Louisiana and elsewhere in the Southern States. Field levees are constructed as for irrigated rice, but rainfall supplies the needed water. Fairly satisfactory yields are produced in seasons of uniformly high rainfall, but average or dry seasons mean low yields.

Floating rice is grown in southeastern Asia where streams overflow during the growing season. Some especially adapted varieties are sown before the flood season. The waters rise slowly, and the fields remain inundated for several weeks. Meanwhile the plants elongate rapidly as the depth of the water increases. The culms are weak but are supported by the water. When the water recedes, the plants lodge, but enough straight growth remains so that the panicles are off the ground and seed is produced. Rice produced in that way must be harvested by hand.

Land suited to rice usually is rather level and has a definite drainage pattern. In the Philippines and elsewhere in southeastern Asia, however, rice is grown on terraces in mountain regions, where sometimes the entire mountainside has been converted into a series of rice paddies. Spillways permit the water to flow down from one terrace to another.

In the United States the irrigation water is diverted from streams or is pumped from rivers, bayous, wells, lakes, or reservoirs. The water is delivered into field levees, which are built on the contour and keep the field submerged at a fairly uniform depth.

Rice growing in the United States started in the 17th century near Charleston, S. C. Rice soon became an important crop along the tidal streams in the South Atlantic coastal area. The fields along the streams were divided by drainage ditches and levees into plots of about the same level. The levees were constructed from the earth taken from the ditches. The small fields were next to canals, which carried the water from streams. The canals also connected small streams, formed dividing lines between plantations, and provided for barge transportation during planting and harvest. Floodgates, located above the salt-water line in the streams, controlled the flow of water into the canal. The gates were placed so that water flowed into the canals at high tide and was shut off at ebb tide. The gates could be opened at low tide to drain the fields.

New settlers, coming in after 1865, attempted to grow rice on the prairie in southwestern Louisiana.

They found that rice grew very well there, and that the sluggish streams, called bayous, provided plenty of water for irrigation. The problem was to get the water to the higher lands. The first attempt was to dam up small drainage areas and collect water during the winter. The water was pumped to the field by small pumps driven by steam engines. These systems were improved, until in 1894 the first large irrigation plant was established on
Bayou Plaquemine, about 2 miles from Crowley, La. It first used a vacuum-type pump, which failed in midsummer. The next year a centrifugal pump was installed, but it did not have enough capacity to deliver the water needed for the entire acreage. A larger centrifugal pump, installed in 1896, delivered 5,000 gallons of water a minute, enough for the planted acreage. Many pumping plants were installed on the streams in southwestern Louisiana and southeastern Texas the next few years. Some pumping plants in operation in 1901 delivered up to 45,000 gallons a minute.

The water requirement for rice is rather high, because the fields are submerged for 3 to 5 months.

In California 3 to 8 feet are needed each season. The requirement in Arkansas and Louisiana is 1.5 to 3 feet. The amount of irrigation water required is least in places where the subsoils are relatively impermeable and the seasonal rainfall is high. The normally abundant rainfall cuts the pumping requirements in the rice sections of Arkansas, Louisiana, and Texas, but unusually heavy rainfall may cause breaks in the levees and serious losses of water.

More than 40 percent of the 1953 rice acreage in the United States was irrigated from wells. About 90 percent of the 485,000 rice acres in Arkansas, 40 percent of the 604,000 acres in Louisiana, and 20 percent of the 573,000 acres in Texas, 10 percent of the 394,000 acres in California, and most of the 75,000 acres in Mississippi were irrigated from wells.

Pumping from bayous supplies most of the surface water in Louisiana and Texas. Diversion from large streams is the main source of water in California. The main surface water supply in Arkansas is from reservoirs that range in size from 20 acres to more than 4,000 acres and are filled during periods of high runoff.

Heavy, concentrated pumping has seriously lowered the ground water level in some parts of Arkansas, but other sources of irrigation water are being developed. The recharge of ground water through wells has been considered.

Diesel engines came into common use for pumping water after 1919.

Convenience, low labor requirements, and reasonable initial and operating costs have since caused a shift to electric power for irrigating rice. About 1,800 irrigation installations, nearly 50 percent of the total, were powered by electricity in Arkansas in 1955. In Louisiana, of a total of 1,061 wells, 450 were powered by diesel engines, 212 by natural gas, 105 by electric motors, and the remainder by other units.

The efficiency of the pumps has improved rapidly, so that outlays for electricity have dropped. Pump bowls ordinarily had an efficiency of about 20 or 40 percent in 1915. Modern pump bowls of suitable design have efficiencies of about 83 percent.

Costs of electric power for irrigating rice in Arkansas ranged from 4.68 to 11.24 dollars an acre in 1954. Fixed or overhead costs averaged about 3.75 dollars an acre. The electric rates for rice irrigation are lowest for pumps that operate continuously during the season, but it may be advantageous to pay slightly higher rates in order to have a larger flow of water during some periods and to reduce the time expended in irrigating. A flow of 5 gallons a minute an acre delivers the average of 22 acre-inches required in slightly more than 80 days, while 7.5 gallons requires a little less than 60 days. The average well flow on Arkansas rice farms has been estimated at about 7.1 gallons a minute an acre.

Farm experience thus indicates a preference for more than the minimum.

The water is conveyed from the pumps, streams, or reservoirs in canals, from which it is diverted into laterals, field ditches, and finally the field checks, or levees. Those structures should be located by a competent engineer and be of proper size to provide water when and where it is needed.
When the rainfall is below normal in the gulf coast of Louisiana and Texas, the water level in the streams that supply irrigation water often is so low that brackish water encroaches from the Gulf. The concentration of chloride salts may become so high that the yield and quality of the rice is reduced or the crop ruined.

Water that contains more than 35 grains of salt a gallon (600 parts per million) should not be used to irrigate young rice if the soil is dry and if the water is to remain on the field. Rice watered continuously with water containing 35 and 75 grains of salt a gallon (600 and 1,300 parts per million) was reduced in yield about 25 and 70 percent, respectively, and the rice was of lower quality than when water containing 25 grains a gallon was used. The rice plant can tolerate higher concentrations of salt, in the later stages of growth, although very high concentrations may kill the plants or make them sterile. The Blue Rose variety is more tolerant to salt than some other varieties and has made satisfactory yields when the water contains salt concentrations of 75, 150, 200, and 250 grains a gallon in the tillering, jointing, booting, and heading stage, respectively. Some of the newer varieties probably would be damaged seriously by those amounts of salt.

If a field has been watered with fresh water and the supply is then replenished with salt water, the damage will be less than if the salt water is put on dry soil. The reason is that the salt is more concentrated in the dry soil and more of it moves into the root zone, whence it is taken up by the plants. Rice grown on clay soils may not be injured by salt water to the same extent as on lighter soils, because less water is used and less is lost by seepage.

About 3 tons an acre of salt are added when water containing 50 grains of salt a gallon is used for the whole growing season. The accumulations of salt over the years may deflocculate the soil, so that stickiness, compactness, and impermeability increase. The deflocculated soil is hard to cultivate and produces low yields.

Well water, used to irrigate a large part of the rice acreage in Louisiana and Arkansas, usually is low in chlorides. In the lower basin of the Vermilion River in Louisiana, however, salt water encroaches on the Chicot Reservoir when the river is intruded by salty water.

Water from shallow wells sunk into Quaternary beds in Arkansas contains 75 parts per million of calcium and 22 parts per million of magnesium. Soils that have been irrigated for many years with this well water have increased in pH ratio from about 5.0 up to as high as 8.0. That change from a highly acid to a highly alkaline reaction is due to the annual addition of about 1,500 pounds an acre of limestone equivalent. The increase in available calcium and magnesium lowered the availability of phosphorus in the soil. If a new source of water is obtained that is low in dissolved minerals, those changes may be reversed.

Rice has been grown in order to reclaim saline or alkali lands in California. It is successful when the water is appreciably lower in dissolved minerals than is the soil, the soil is relatively permeable, and drainage is adequate. Crops that are not salt-tolerant can be grown on the alkali soils after 2 or 3 years of rice.

The temperature of the irrigation water is important. The temperature may be too low early in the season and too high late in the season for maximum emergence of rice sown in the water. Germination is retarded when the temperature of the water is below 70° F. Roots develop poorly when the temperature is above 85°, perhaps because of the low oxygen content of warm water. The temperature of the water from shallow wells in Arkansas and from streams in California is usually 65° F. or lower. When such cool water goes directly into the field, the rice growing near the water inlet usually is retarded. Such "cold water" rice may ripen 7 to 10 days later than...
the rice in the rest of the field, and the
difference interferes with harvesting.
The way to avoid that condition is to
hold the water in a warming basin or
to have several inlets to the field. The
water from deep wells in Arkansas and
from the streams, lakes, and reservoirs
in the South usually is warm enough
for rice.

Water is delivered usually to the
highest point in the field by canals or
pumps. It passes into successively
lower paddies through openings or
metal checks in the levees. Metal
checks provide permanent control of
the maximum height of water in each
paddy. Field levees must be properly
spaced and on the contour to provide
uniform irrigation and complete drain-
age. Levees are spaced at a difference
of about two-tenths of a foot elevation
between adjacent levees. Smoothing
the land before surveying results in
more accurate surveying, more uni-
form irrigation, and better drainage.

Either levee disks or pusher-type
machines form levees with sloping
sides and high enough to hold water 4
to 6 inches deep on the subfields or
paddies without overflowing into the
next lower paddy. Low, sloping levees
reduce production costs because they
can be seeded and thus produce con-
siderable rice while reducing weed
growth.

Two general methods of seeding and
irrigating rice are practiced in the
United States. One is to drill the seed
in the soil; submergence follows. The
other is to broadcast the seed in the
water.

Most of the rice in the Southern
States is drilled or is sown with an
endgate seeder and covered with a
disk or harrow. The soil is then irri-
gated lightly if moisture is needed for
germination and growth of seedlings.
Later the soil is submerged when the
plants are 6 to 8 inches tall.

The seedbed is prepared by plowing
with a moldboard or disk plow in the
fall, winter, or early spring, followed
by disking and harrowing, and some-
times the use of a heavy plank drag to
break the clods. Heavy soils, such as
Sharkey or Beaumont clay, usually are
dry by the time the land has been pre-
pared and seeded so that it becomes
necessary to irrigate to germinate the
seed unless rain comes soon after
seeding. The field must be drained
after the early irrigation, because rice
seed that is covered with an inch or
more of soil will not germinate in
standing water. This practice, how-
ever, also provides ideal conditions for
the germination and growth of weedy
grasses.

Experiments started in 1914 on new
rice lands in California showed that
the best yields were obtained when the
land was submerged to a depth of 6
to 8 inches about 30 days after the rice
seedlings emerged. This method, how-
ever, favored the invasion and increase
of weedy grasses, particularly barn-
yard grass (Echinochloa species), and
therefore was not suited to old rice
lands. Experiments in Arkansas dem-
onstrated that a heavy infestation of
grass reduces the yield of the rice by
50 percent or more. Water-seeding
methods were developed to control the
weedy grasses.

The seeding of rice in water was
started in California as a way to con-
trol barnyard grass. Low spots covered
with water when a field was being
drilled often were sown by hand
broadcasting, and such spots were
observed to be relatively free from
barnyard grass. Experiments in seed-
ing rice in the water about 6 inches
deep demonstrated that many grasses
could be controlled in that way, and
good stands of rice and high yields
could be obtained. The rice germi-
nates and emerges through 6 inches of
water, whereas the grasses seldom get
to the surface of the water. At first the
rice was sown with a broadcast seeder.
Broadcasting in water with an endgate
seeder stirs up mud, which makes it
hard for the driver to follow a straight
line. The airplane is more satisfactory
for sowing submerged land. The air-
plane operator is guided by flagmen,
one at each end of the field, who pace off the distance (about 30 feet) that the plane can sow in one trip across the field.

Airplane seeding was attempted first near Merced, Calif., in 1929, for reseeding a field in which the rice had been destroyed by mud hens. A fair stand of rice and a satisfactory yield were obtained. Several California growers seeded their rice with an airplane in 1930. Now airplane seeding is the common practice among growers in California. Experiments with water seeding in Arkansas and other Southern States developed modifications, which were adapted to the other areas.

The prevailing method of growing rice in California is to plow the land in early spring to a depth of 4 to 6 inches and allow the soil to dry for 7 to 10 days. A satisfactory seedbed can then be prepared by harrowing twice and floating once with a heavy plank drag. The field levees are then put up, the floodgates put in place, and the field flooded to a depth of about 6 inches. Seed that has been soaked for 36 to 48 hours is then sown with an airplane at the rate of 135 pounds of seed an acre. The field is kept submerged to a depth of 5 to 7 inches until the rice is ready to drain before harvest. Preparing the seedbed when the soil is dry gives better control of some of the aquatic weeds and grasses that cannot be controlled by flooding and retards the growth of algae (green scum) on the surface of the water.

In the water-seeding method in Arkansas, the land usually is plowed in winter, and the seedbed is prepared by disking 2 or 3 times and then harrowing. Frequently the soil also is tilled to a depth of about 8 inches with a field cultivator to provide space for the application of cool irrigation water that contains oxygen, which is necessary for early root development. The water below the surface of the soil remains cool and retains considerable oxygen, whereas the surface water is warmed by the sun, and much of the oxygen escapes. The levees are completed after the soil is worked with the field cultivator, and the field is then cultivated with a springtooth harrow, which leaves shallow furrows and ridges that prevent drifting of the seed. The floodgates are then put in, the field submerged to a depth of 4 to 6 inches, and the rice sown from an airplane. Seeding is done as promptly as possible, as poor stands usually are obtained when the water has been on the field longer than about 4 days before seeding. The seeding rate is 100 to 110 pounds of dry seed an acre. The water is usually drained after 5 to 6 weeks for the control of the rice water-weevil and to provide dry soil for top dressing with fertilizer.

The water-seeding method as practiced on heavy clay soils in Texas and other Southern States consists of plowing and disking the land to kill vegetation, but the surface is left rough. The levees are then put up and the field is irrigated enough barely to cover the land. The flooded field is then cultivated with a light disk or heavy spike tooth harrow. The soaked seed is sown immediately from an airplane. Sometimes a shallow flood is left, but usually the excess water is drained off the field after seeding and the seeds are covered with a thin film of mud. Germination of the presoaked seed is rapid. As soon as the seedlings emerge, a shallow flood of water is added to fields that were drained after sowing. The depth of water is increased gradually up to 5 to 7 inches as the seedlings elongate. The water may be drained 1 or 2 times during the growing season to control insects or to apply fertilizer.

Correct timing of irrigation and drainage may help to control certain insects. The root maggot has reduced yields up to 29 percent in some areas, and increases of 11 to 27 percent in yield have been obtained by draining the field when heavy pruning of the rice roots by the maggots is evident. That usually occurs about 17 to 28 days after the field is first submerged.
The practice, however, makes an ideal breeding place for rice-field mosquitoes (*Psorophora confinnis* and *P. discolor*). They lay their eggs on the soil from which water has been drained. The eggs hatch when the soil is again submerged. The southern corn rootworm, chinch bugs, sugarcane beetles, and the southern grass worm, which often are serious pests in some places, often can be controlled somewhat by submerging the field when seedlings are attacked or by holding the water on the field as long as possible when the rice is attacked as it is nearing maturity.

Several diseases of rice can be controlled or the losses from them can be reduced by using the correct irrigation methods. Straighthead is a nonparasitic disorder characterized by failure to set seed, usually accompanied by a distortion of the palea and the glumes. Straighthead sometimes is destructive in the Southern States on soils high in organic content. It occurs most frequently on sandy, loamy, or mixed soils but rarely on clay soils. Effective control is obtained by draining the field just before the panicle bud forms—usually 6 to 8 weeks after emergence, depending upon length of growing season of the variety. The field is flooded again as soon as the soil is dry.

Stem rot, a fungus disease, first appears in midsummer as small, discolored areas on the sheaths of the rice stem near the water line. The most satisfactory method of control is to drain the water from infected fields before the infection reaches the culm. Water should then be added from time to time to keep the soil saturated but not submerged. Such treatment may result in reduced losses from lodging, but a slight reduction in yield is usual where infection is light. Such irrigation should not be practiced unless infection is heavy.

Blast, caused by the fungus *Piricularia oryzae*, has caused losses in yield in the Southern States from time to time. Usually the most obvious and damaging phase of the disease is the infection of culms and panicles after the plants have headed. Infection also occurs in the seedling stage and causes a reduction in stand before the field is submerged, but then injury may be reduced by submergence of the land as soon as the leaf spots become evident.

C. Roy Adair is an agronomist in charge of rice investigations in the Cereal Crops Section, Field Crops Research Branch, A. R. S., at Beltsville, Md. He has written many bulletins, circulars and other publications on rice culture and breeding.

Kyle Engler is head of the Department of Agricultural Engineering, College of Agriculture, University of Arkansas, Fayetteville. He carried out many studies on the use of water for rice irrigation and on the use of underground water in the Grand Prairie region of Arkansas. He has written many bulletins and articles on these studies.

**Growing 100-Bushel Corn With Irrigation**

H. F. Rhoades and L. B. Nelson

Corn cannot be grown profitably without irrigation in the arid sections of the West. Irrigation changes corn from a marginal to a profitable crop in semiarid areas. It removes the ever-present hazard of drought in the subhumid area and the humid East.

Corn yields greater than 150 bushels an acre have been obtained in experiments under irrigation at several places in dry sections of the West. Such yields were obtained only by the use of the best combination of practices, but farmers in those areas can expect to improve yields by adopting similar practices.

Benefits from irrigating corn vary from year to year in the subhumid and humid sections. Experiments at the Redfield Development Farm in South Dakota showed increases in yield due to irrigation of 117 and 27 bushels an