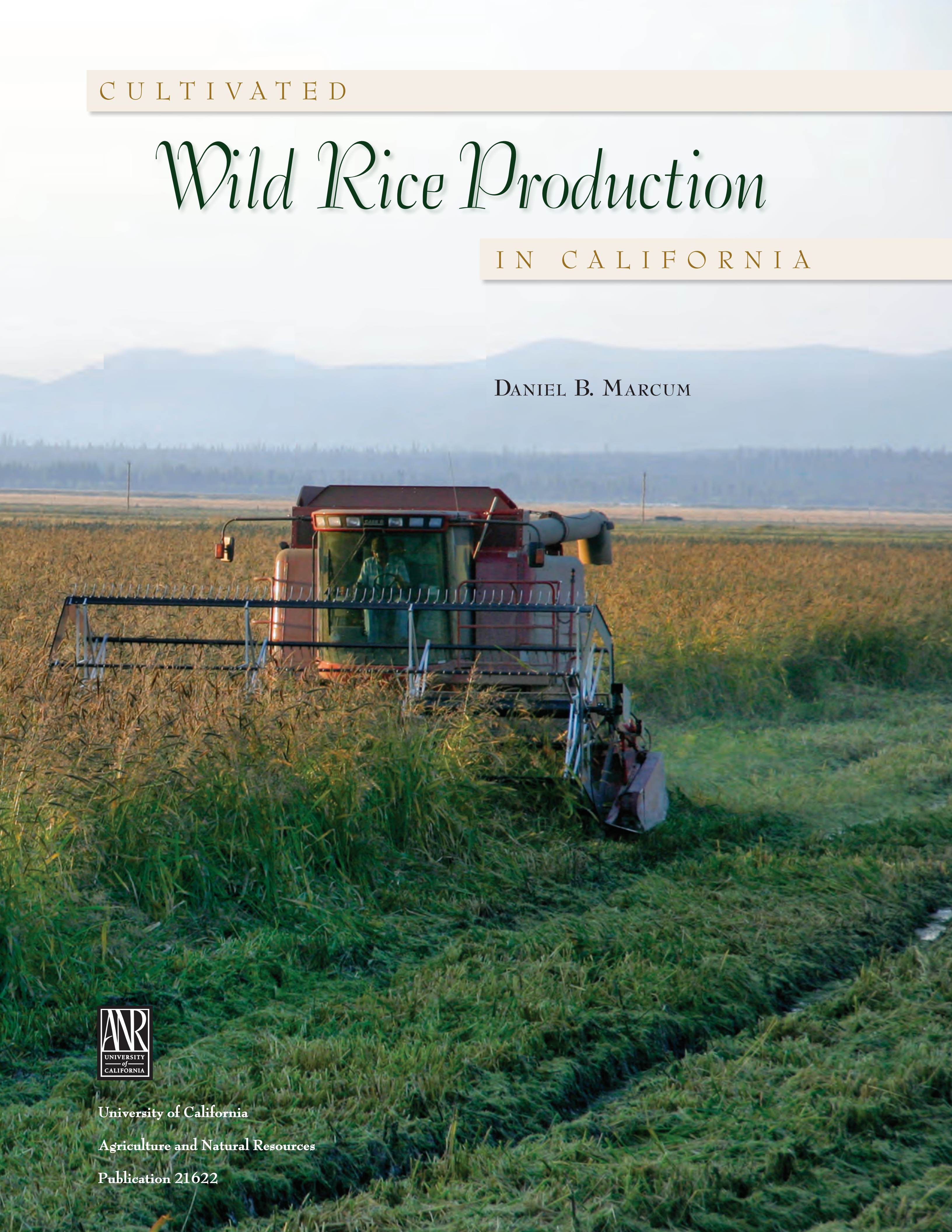

CULTIVATED

Wild Rice Production

IN CALIFORNIA

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UNIVERSITY of CALIFORNIA

University of California

Agriculture and Natural Resources

Publication 21622

CULTIVATED Wild Rice Production IN CALIFORNIA

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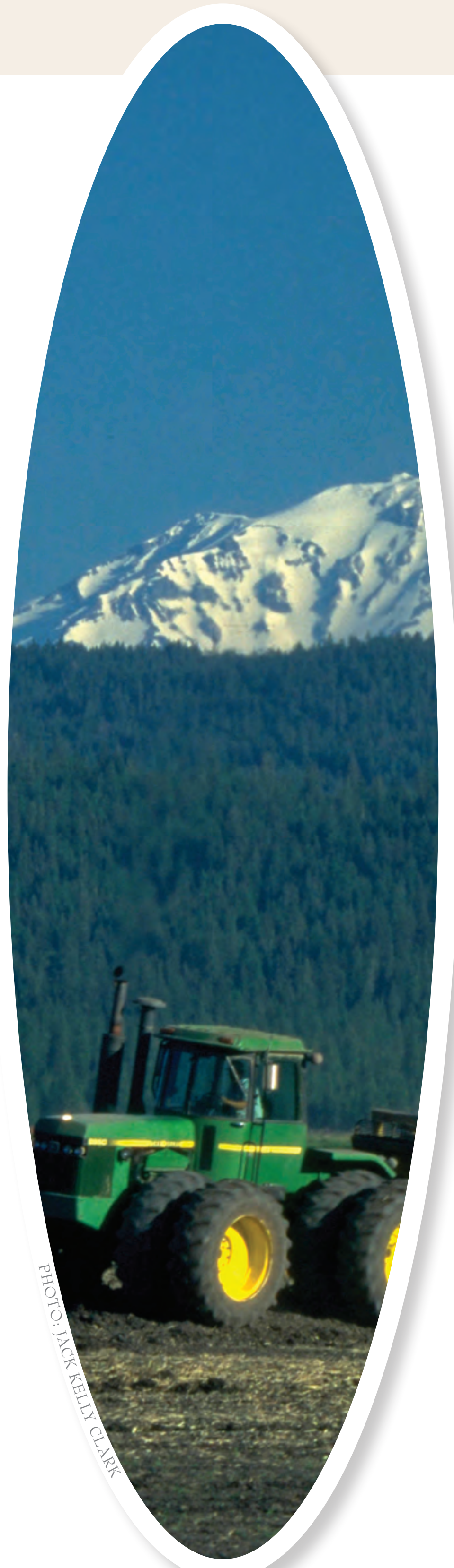
To convert	to	perform this operation
inch (in)	centimeter (cm)	in × 2.54 = cm
foot (ft)	meter (m)	ft × 0.3048 = m
acre (ac)	hectare (ha)	ac × 0.4047 = ha
acre-foot (ac-ft)	cubic meter (m^3)	ac-ft × 1,233.48 = m^3
ounce (oz)	gram (g)	oz × 28.35 = g
pound (lb)	kilogram (kg)	lb × 0.454 = kg
ton, U.S. (T)	metric ton (t)	T × 0.907 = t
degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F – 32) ÷ 1.8 = °C
parts per million (ppm)	mg/kg	1 ppm = 1 mg/kg



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Wild Rice Production

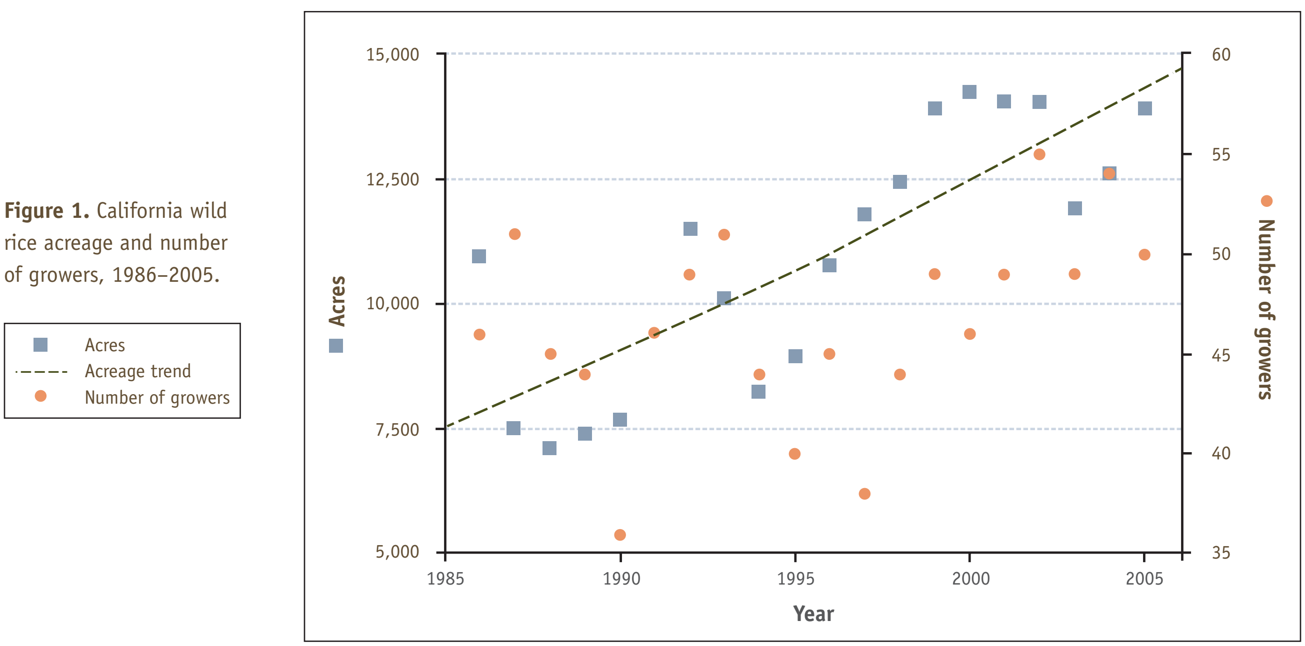
IN CALIFORNIA

Introduction

Originally found in lakes and rivers, wild rice (*Zizania palustris* var. *interior* [Fassett] W. Dore) is a native North American grain. Wild rice differs from rice (*Oryza sativa* L.). Both plants are in the grass family (Graminae), but each belongs to a different genus: *Zizania* for wild rice and *Oryza* for rice. Of the four species within the *Zizania* genus, only *Z. palustris* is used for food, producing a seed grain that must be heat-cured after harvest both for proper storage and so that it can be cooked and eaten.

Cultivated wild rice production in California began in the Sacramento Valley in 1972 and by 1986 California was the largest center of commercial production in the world. Development spread from Sacramento, Yuba, and Sutter Counties north to Tehama County and west to Lake County and into northeastern California's Shasta, Lassen, and Modoc Counties. About 57 percent of this production is in the Sacramento Valley and the remaining 43 percent is in northeastern California. From 1999 to 2005, approximately 50 growers produced wild rice on about 13,500 acres in nine California counties (figures 1 and 2).

Figure 1. California wild rice acreage and number of growers, 1986–2005.



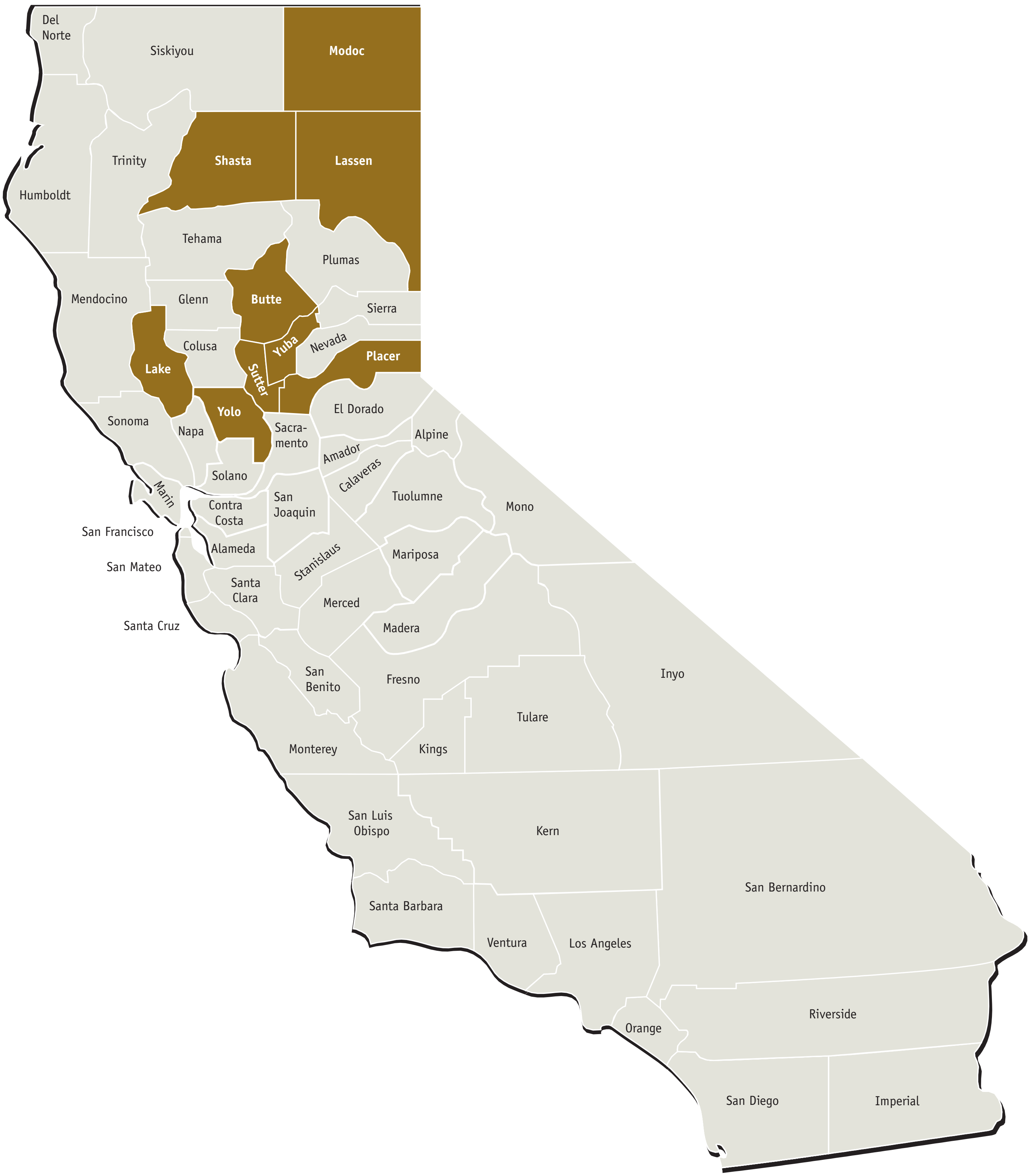


Figure 2. California counties with wild rice production, 2005.

Wild rice has been a successful crop in California because production economics have been favorable; the crop adapts easily to basins that have been used for rice production in the Sacramento Valley, and flat irrigated pasture land in northeastern California can be modified to accommodate the crop without too much expense. The California climate is advantageous for production of wild rice. Dry, rainless summer weather limits development of some diseases, and several insect pests known to cause economic damage to wild rice grown in other states are nonexistent in California. The general absence of thunderstorms at harvest time reduces the risk of major preharvest losses. A long growing season in the Sacramento Valley provides flexibility in scheduling planting and harvest dates. In northeastern California, the colder, shorter growing season that comes along with the higher elevation (>3,000 ft) and latitude (>41°N) provides sufficient winter chilling to break seed dormancy, allowing production both from fall seedings and from volunteer seed left in the field after harvest.

PHOTO: ERV OELKE

Figure 3. Wild rice germination.

Biology of the wild rice plant

Wild rice is an annual plant that grows from seed. Seed germination is evident when the coleoptile that covers the leaves breaks through the tough outer layer of the seed (figures 3 and 4; table 1). The mesocotyl, a short stem between the stem apex and the seed, extends through up to 2 inches of flooded soil to the soil surface, where the first node is established (the

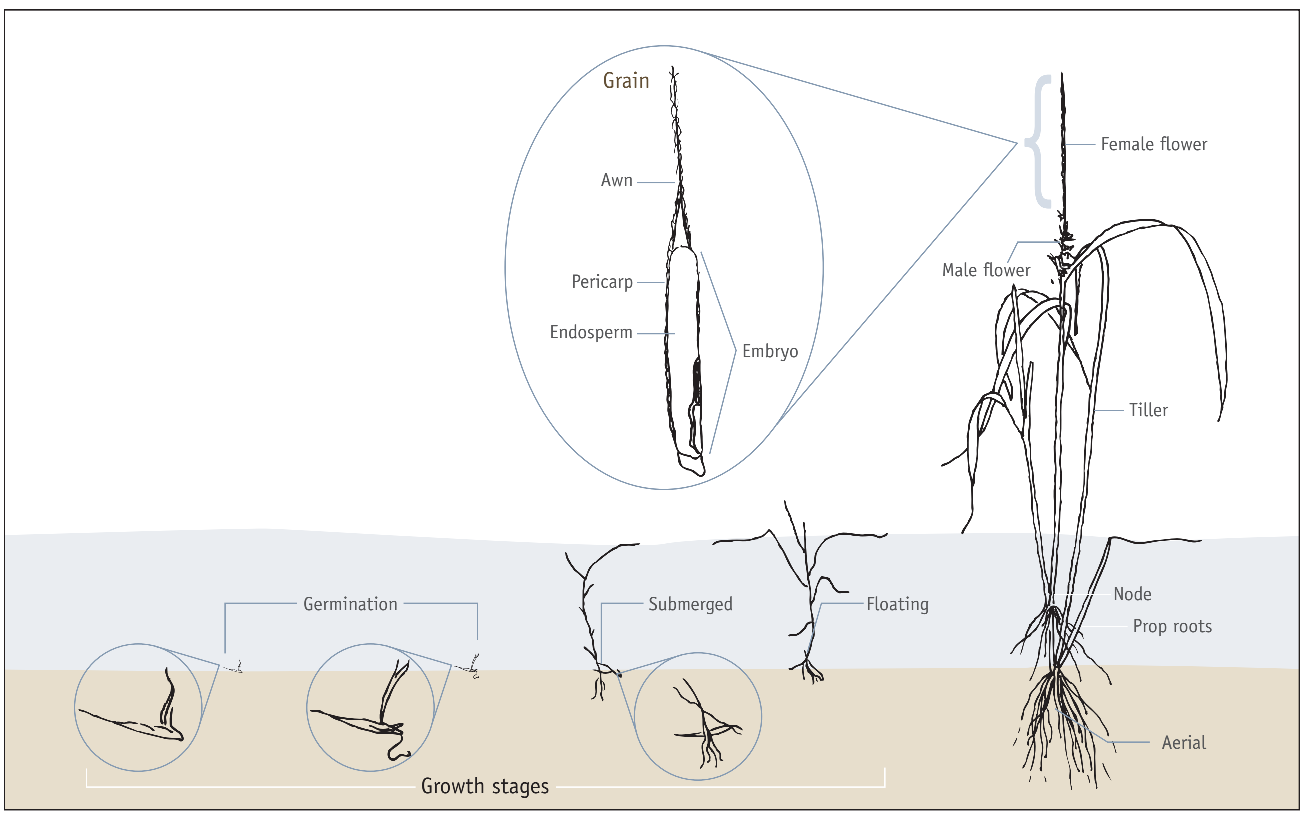


Figure 4. Life cycle of wild rice.

Table 1. Wild rice growth stages

General growth stage	Wild rice growth stage scale (WRGSS)
Germination (Stage 0)	• Seed dormant • Endogenous dormancy broken • Coleoptile emergence • Secondary root initiated • First leaf extended
Seedling and leaf development (Stage 1)	• Submerged leaves only • First floating leaf • Second floating leaf • Bow stage (partially aerial) • First aerial leaf • Second aerial leaf emerging • Third aerial leaf emerging • Fourth aerial leaf emerging • Fifth aerial leaf emerging • Sixth aerial leaf emerging
Tillering (Stage 2)	• Main stem only • Main stem and one tiller • Main stem and two tillers • Main stem and three tillers • Stem and four or more tillers
Stem elongation (Stage 3)	• Nodes not separated • Node separation initiated • >1 inch of node separation • >3 inches of node separation • >6 inches of node separation • Flag leaf emergence
Boot (Stage 4)	• Inflorescence visible–dissected • Boots visibly swollen • Boots fully swollen • First awns visible
Inflorescence emergence (Stage 5)	• First spikelet just visible • 1/3 of female portion emerged • 2/3 of female portion emerged • Female portion emerged • 1/2 of male portion emerged • Male portion emerged • Anthers non-dehiscent • Anther dehiscence initiated • Complete anther dehiscence
Grain elongation (Stage 6)	• Grain elongation initiated • 1/4 grain elongation • 1/3 grain elongation • 1/2 grain elongation • 2/3 grain elongation • 3/4 grain elongation • Grain fully elongated
Milk (Stage 7)	• Early milk • Medium milk • Late milk
Dough (Stage 8)	• Early dough • Soft dough • Hard dough
Grain ripening (Stage 9)	• Easily dented by thumbnail • First seeds turning brown • Vascular strand expanded • Slight dent with thumbnail • Vascular strand brown • 1/2 of panicle's seed darkened • Vascular strand collapsed • Panicle dark and hard

Source: Percich et al., in Minnesota Wild Rice Report, 1987, page 59.

mesocotyl is very short if the seed is on the soil surface). As the mesocotyl elongates, a single primary root emerges and grows downward. Secondary roots arise at the first node and, occasionally, at the second and third nodes. The roots lack root hairs and are straight, spongy, and generally white. The root system of the mature plant is shallow and has horizontal roots with a spread of 8 to 12 inches. The stem space between lower nodes (the internode) is short and becomes longer between each subsequent node. The last node bears the panicle (seed-bearing portion) of the plant and may have an internode 24 to 36 inches long. Wild rice grows as tall as 7 to 8 feet above the soil surface. Plant size depends upon variety, fertility level, water depth, plant density, and time of seeding.

All nodes except the first and last have a leaf sheath and leaf blade. A prominent, clasp-like membrane is found at the junction of the sheath and the blade. Seedlings have three leaves (which remain submerged) within 3 weeks of germination. The next two leaves float on the water's surface for typical water depths. This stage of growth is easy to recognize as the *floating leaf stage* (figures 5 and 6). The floating leaves and the final three to six upright (aerial) leaves have a waxy surface (figure 7). The blades of aerial leaves are from ¾ to 1 inch wide and 16 to 30 inches long. The midribs of aerial leaves are not centered and are more prominent on the lower surface than on the upper.

The stem diameter of the wild rice plant varies from ¼ to ½ inch. Internodes are hollow and divided by thin, porous partitions that allow the diffusion of gases up and down the stem. Up to 50 additional secondary stems (tillers) can originate from the basal nodes. The primary and secondary tillers produce panicles. The number of tillers produced by a wild rice plant corresponds to plant density: a dense stand produces few tillers and a sparse stand produces many tillers. Seeds produced on primary and secondary tillers often reach maturity at different (asynchronous) dates.

The panicle is 18 to 20 inches long and divided equally into a male (staminate) part (the lower half of the panicle) and a seed-bearing female (pistillate) part (figure 8). Occasionally, a plant will have panicles with all pistillate flowers and no staminate flowers. These plants are termed *pistillate* and are considered undesirable because they lodge easily and populations are difficult to keep genetically stable. Some flowers have both male pollen parts (yellow-colored anthers) and female receptive parts (stigmas) in the transition zone between the pistillate and the staminate sections and could be self-pollinated. The staminate portion of the panicle is spreading in shape and has 12 to 15

PHOTO: JACK KELLY CLARK

Figure 5. Wild rice at *floating leaf* growth stage.

PHOTO: JACK KELLY CLARK

Figure 6. Volunteer wild rice at *floating leaf* growth stage.

PHOTO: JACK KELLY CLARK

Figure 7. Wild rice at the *bow* growth stage.

branches; each branch is 4 to 5 inches long and has 50 to 60 flowers. Mature staminate flowers produce windborne pollen from their anthers (figure 9). Some plants may have short-stemmed staminate flowers: this condition is termed *bottlebrush* (figure 10). Bottlebrush-type plants often fail to produce pollen, but this characteristic is not considered a yield-limiting factor in wild rice production since the overall field still has a sufficient number of male-fertile plants.

Each wild rice panicle contains from 100 to 200 pistillate flowers. The pistillate portion of the panicle has flowers on branches that lay flat (appressed) on the stem. Branches vary in length from 1 to 5 inches; those on the top are the shortest and those lowest on the stem are the longest. Occasional plants have pistillate branches that are not appressed. The term for this type of panicle is *crow's-foot* (figure 11).

The pistillate flowers emerge from the leaf sheath before the staminate flowers. On a given plant, the stigmas are receptive for 3 to 4 days before its anthers shed pollen, so wild rice usually is cross-pollinated. Each fertilized pistillate flower produces a single seed, which matures in 19 to 25 days. Fertilization is evidenced by withering of the stigma. Within a week of fertilization, the presence of fluid seed contents shows that the seed has reached the *milk stage.* The seed contents solidify within a week, and after 3 to 4 weeks the purplish black seed has dried sufficiently for harvest (figure 12). The mature seed is surrounded by a hull before and after harvest and has a prominent awn ½ to 2 inches long.

Development of wild rice varieties

The most significant problem in the harvesting of native wild rice is *shattering,* when the mature seed falls from the panicle. Native wild rice has a tendency toward shattering, which necessitates a multiple-pass harvest that is uneconomical in California. The discovery of nonshattering wild rice plants led to notable gains in grain yield and allowed single-pass harvest using a combine. Small numbers of nonshattering plants that retain both their pistillate and staminate flowers beyond maturity can be observed in all wild rice populations. These plants are termed *flag plants* because their male flowers remain, flaglike, on the plant after pollen is shed. Seed collected from flag plants in a Minnesota wild rice basin owned by Algot Johnson were the basis for the first nonshattering variety, called 'Johnson.' Currently, no completely nonshattering wild rice variety exists.

PHOTO: JACK KELLY CLARK

Figure 8. Wild rice panicle.

PHOTO: JACK KELLY CLARK

Figure 9. Male wild rice stamens have yellow anthers.

Varieties commonly grown in California

All wild rice varieties have some characteristics in common. They all shatter and are susceptible to disease. They lodge if planted at too high a density, if subjected to too much nitrogen (N) fertilization, or grown in water that is too deep. Because differences between varieties are sometimes difficult to recognize, the best method for identifying wild rice varieties is through direct knowledge of the seed source.

'Johnson.' 'Johnson' was the first variety grown in California. 'Johnson' plants are tall, mature late, and have wide leaves with a panicle color ranging from white to pale green and occasionally purple. No certified 'Johnson' seed is available.

'K2.' Until the release of 'Franklin,' the variety 'K2' was the dominant variety grown. 'K2' has a medium height, early-to-medium maturity, and medium-width leaves, and is recognized by its mostly purple panicles (figure 13). 'K2' was developed by the Kosbau brothers in Minnesota in 1972. No certified 'K2' seed is available.

'Franklin.' The University of Minnesota released 'Franklin' in 1992 after improving the shatter resistance of 'K2.' 'Franklin' is recognized by its long retention of purple staminate flowers as the grain matures. 'Franklin' yield usually exceeds that of either 'Johnson' or 'K2.' Certified 'Franklin' seed is available in California from the Foundation Seed and Certification Services, University of California, Davis CA 95616 (http://ccia.ucdavis.edu).

PHOTO: JACK KELLY CLARK

Figure 10. Bottlebrush-type wild rice panicles.

PHOTO: JACK KELLY CLARK

Figure 11. Crow's-foot–type wild rice panicle damaged by blackbirds.

PHOTO: JACK KELLY CLARK

Figure 12. Ripening wild rice grain.

PHOTO: JACK KELLY CLARK

Figure 13. Color difference between 'K2' *(foreground)* and 'Johnson' *(background)* wild rice.

Wild rice growers who want to grow a known variety of wild rice should plant only certified seed. Uncertified seed is common seed produced by growers without strict production standards. Purchasers of uncertified seed are buying wild rice populations of unknown origin and are accepting the risk of variety mixes and unwanted weeds.

The wild rice season in California

Wild rice requires about 90 to 115 days to produce mature seed, but the actual number of days from planting to seed maturity varies widely. Ideally the crop is planted in spring, but if the planting date is delayed to summer with its longer day lengths, the plants may have fewer tillers, less height, earlier flowering, and earlier production of mature seed. Deeper water in the field will slow the time from emergence to floating. Warm temperatures induce accelerated growth and maturation. Plants raised in cool temperatures have more tillers and more pistillate flowers per panicle.

Wild rice in the Sacramento Valley is spring-seeded. Planting begins in February and March, and the majority is planted in April and May. If planting dates are delayed into June, high temperatures may cause blanking (failure to form seed), blackbird damage may increase, and harvest schedules may conflict with the harvest of conventional rice.

Growers in northeastern California have lower seeding costs because wild rice can volunteer from shattered seed left in fields from the previous crop. New wild rice plantings are spring-seeded in April and May, with some planted in June following cultivation to incorporate fertilizer and control weeds. Fall planting of wild rice in northeastern California is possible, but rarely practiced because of concern over low winter survival rates for the seed. Thus, fall seeding of wild rice is limited to the few sites in northeastern California where flooded conditions make spring cultivation impossible.

Floating leaves are visible a month after germination and aerial leaves appear 10 days later. *Jointing* (the elongation of internodes) starts about 8 weeks after germination, and the *boot stage* (panicle formed but not yet emerged) occurs a week later.

Flowering begins in June or July and grain formation in July or August. The crop is harvested from July to September.

After harvest, fields are disked to incorporated crop residue. In northeastern California, harvested basins are often rolled with a heavy metal cylinder to remove harvest tracks and spread the water to shallower depths so the basin can dry more quickly before disking. Fall incorporation of residue into the soil is important for increasing the breakdown of crop residue and for disease control. In northeastern California, fall incorporation also reduces overwintering seed losses caused by desiccation and wildlife feeding.

The major disadvantage of continued volunteer crop production is that varieties begin to develop a higher rate of shattering (figure 14). Volunteer stands should be terminated if shattering-type plants are easily sighted. Unlike flag plants, these plants lose their male flowers prematurely. Stands with high numbers of shattering plants (>10%) should be eliminated by not growing a crop *(fallowing)* or growing an alternative crop before spring-seeding wild rice for the next season. Cultural practices intended to eliminate volunteer stands will also help reduce weed populations.

Basin construction

The best sites for wild rice production are on soils with impenetrable hardpan, claypan, or poor drainage, since the basins must be flooded for the entire production season. Sandy soils often require excessive amounts of water to keep the basins flooded. The field should be located on land where leveling costs will be minimal. Extensive leveling is not only costly, it can also expose soil that is low in nutrients or organic matter. The site should be drainable for tillage and harvest. If the wild rice crop is preceded by a perennial crop such as irrigated pasture, plow or till or disk the area a year or more before basin construction to facilitate the breakdown of organic matter for subsequent land leveling.

Many wild rice fields in the Sacramento Valley are largely unmodified rice basins from conventional rice. Modifications may include construction of additional levees to allow access for control of birds and increased levee height to allow greater water depth. All of the wild rice basins in northeastern California have been constructed specifically for wild rice, but some are rotated to perennial grass crops when wild rice yields decline due to higher disease incidence, increased salinity, or excessive shattering.

PHOTO: JACK KELLY CLARK

Figure 14. Early loss of male florets in shattering-type wild rice.

Basin construction requires a detailed topographic survey of the land to establish contour lines for levees. Levees should be positioned so the difference in water depth across a basin will be sufficient to allow drainage at harvest but will not exceed 6 inches (preferably less) across an individual basin. A ½-tenth slope amounts to a 6-inch fall in 1,000 feet. Too great a slope may cause variations in water temperature and crop maturity across the basin and may limit the grower's ability to use water as a management tool to suppress weeds on the shallow side. Many growers laser-level their basins to near-zero grade and harvest in partially drained basins.

Levee crests should be a minimum of 3 feet above field grade to allow a water depth of up to 18 inches. Exterior perimeter levees should have a minimum top width of eight feet to allow motor vehicle access (figure 15). Inner levees that border interior basins should have a top width of at least 6 feet to accommodate travel with an all-terrain vehicle. The steepest side slopes of levees should be 1½:1 (1½ feet of horizontal distance for every 1 foot of vertical drop) for most soils. The slope should be 3:1 for soils that erode easily. Levees on organic soils (over 10% organic matter) sometimes fail to hold water back. It is best to mix some mineral soil with an organic soil, especially on the side slopes. If your levees leak, construct exterior ditches to recycle water.

Access roads should be designed as part of the levee system. It is helpful to have an access road leading to every basin: this facilitates bird control activities, movement of equipment, and observation of the developing crop. Place a culvert or other permanent structure in any location where a road crosses a drainage way. Use long culvert pipes so the *weirs* (the gates that regulate water flow in and out of basins) will not interfere with equipment movement and weed control on levees. Position the weirs strategically to allow fields and basins to be flooded quickly and drained completely. *Flashboards* (wooden boards placed horizontally in vertical weir slots to block water) are used to raise water levels in the basin and are later removed to allow the water to drain.

The most flexible design for the irrigation system allows independent flooding of individual basins. This allows the grower to treat each basin individually if necessary and allows the field to be adapted easily to rotation crops. Most irrigation systems, however, are designed to simply let water flow serially from the highest basin to the lowest, thus keeping construction costs low. Ditches may be either inside or outside of the perimeter levees, but in any case they should allow complete drainage of the basins. Ditches are usually exterior to the field or basin and are useful for recycling return water. Exterior ditches can also be used to prevent any flooding into adjoining property

PHOTO: JACK KELLY CLARK

Figure 15. Wild rice levee with external drain ditch.

that may otherwise be caused by water seeping through or under levees. Interior ditches are desirable in basins with organic soils because they maximize drainage at harvest time.

Water management

Wild rice must grow in flooded conditions for the entire season. The minimum season-long volume of irrigation water needed to grow wild rice is usually 3 to 5 acre-feet of water per acre. Flood irrigation is tricky, particularly if the water flows over many types of soil with varied downward flow (percolation) characteristics.

The water depth for wild rice should be 14 to 18 inches and should never be less than 6 inches. A water depth of less than 6 inches will reduce weed suppression and crop yields. Some growers may increase water levels as much as 24 inches for weed suppression and to maintain minimum water levels on the shallow side of a steeply sloped basin. If the water is too deep and cloudy, though, seedlings may receive inadequate sunlight and die. Deep water also reduces tillering and increases the risk of lodging.

Once the basins are flooded, growers use flashboards to maintain constant water depths. Rapid fluctuations in a basin's water depth can uproot small plants. Also, constant water levels during the floating leaf stage are crucial to the development of the plant. Floating leaves play a critical role in determining yield. The experimental removal of a plant's floating leaves can reduce yield by as much as 50 percent. When the plant reaches the floating leaf stage, carbon dioxide for photosynthesis is derived from the stomata on the upper surfaces of the floating leaves rather than from underwater tissues. If the water depth is increased to cover the floating leaves, the plants may not get enough carbon dioxide for optimum growth.

The usual water requirements for wild rice are 6 to 10 gallons per minute per acre on a 24-hour basis, but growers will often increase the water volume, allowing water to flow over the flashboards in weirs to maintain a constant water level. This practice reduces fluctuations in water depth that would otherwise result from normal changes in crop water use between day and night. In northeastern California, growers sometimes use small pumps to recycle water from exterior drainage ditches back into the basins to maintain uniform water levels as a way to avoid the cost of running large well pumps. Higher water flows of 20 gallons per minute per acre are sometimes used for initial flooding or to compensate for levee leaks or deep percolation water losses on permeable soils. Flowing water can also remove suspended sediments from the basin for deposit in a pasture or other filter grass strip. There is no absolute need to flow or circulate the basin water, though, because there is adequate gaseous exchange even in stable (nonflowing) field water.

Wild rice growers generally flood their basins before planting and do not vary water depths for the remainder of the season. The soil must at least remain saturated or the wild rice plants will not survive. Also, if the soil becomes unsaturated, nitrogen (N) as ammonium nitrogen (NH_4^+-N) becomes nitrified to nitrate nitrogen (NO_3^--N), an N form that is not readily utilized by wild rice. In some cases, however, special emergency conditions may warrant a temporary reduction to approximately 2 inches of water or even to saturated soil.

These conditions include

- wind-caused wave action that dislodges seedlings not adequately rooted in soil
- suspended sediment preventing light from reaching seedlings
- excessive midge damage to submerged leaves
- extremely dense algae populations that smother seedlings

Water depth is usually returned to normal after a few days (a week at most), once the problem has passed. In some extreme conditions, such as high midge populations or dense algae growth, growers may lower the water level to the soil surface and the wild rice plants will bypass the floating leaf stage and produce aerial leaves. This strategy is not desirable, however, because of the importance of the floating leaves to the growth and development of the plant.

Wild rice soils should remain saturated during the grain filling period. After grain filling, the basins are drained before harvest. Drainage usually comes very close to harvest time, often within a week or a few days. The water level in the basins can be decreased slowly during flowering so that very little, if any, water remains to be drained from the field before harvest. Care must be taken, particularly during hot weather and on mineral soils, to prevent the soil from drying before the plants are mature. The premature death of plants in drained fields increases the risks of lodging and yield loss. Not all growers drain their fields at harvest: a few find that leaving basins partially flooded at harvest actually helps prevent the accumulation of mud on combine tracks.

Seed management

Wild rice seeds require adequate chilling during the winter or they will not germinate. This dormancy is caused by an impermeable tough tissue layer covered by wax and is controlled by a balance between growth promoters and inhibitors. Growers can force freshly harvested seeds to germinate by carefully scraping and removing the tough tissue layer from directly above the young plant (embryo). Scraped seeds cannot be planted directly, but they can germinate in water and the seedlings can then be transplanted. Threshing damage to seed can sometimes cause direct germination in the harvest bins or on the ground, but plants germinated in this way will not survive the winter.

Wild rice seed to be used for planting is usually stored underwater in 4-by-4-foot steel bins (figure 16). A bin contains 1,200 to 1,500 pounds of seed, enough to plant 10 to 20 acres. Cool water must be added to seed bins immediately after harvest; otherwise, temperatures are likely to rise to 135°F and that will reduce the eventual germination rate. Growers should monitor the seed bins after harvest, changing the water for the first time a few days after harvest and then changing it again every 3 to 4 weeks to leach nutrients and reduce the biological activity of bacteria and fungi in the seed bins. Bins should be kept cool and may be stored in shaded areas on the farm during the fall to save on storage costs. All seed bins should be transferred to refrigerated storage (33°F) by December to ensure that seed dormancy will be broken for planting and at the same time to prevent the growth of seedlings before planting. Seed must be stored below 50°F for at least 5 months in order to break dormancy. After dormancy is broken, the minimum temperature for germination is 42°F and optimum germination comes at 66° to 70°F. When wild rice seed is removed from storage for planting, common practice is to warm it to ambient temperature for 2 to 3 days in order to initiate germination. Seed that is ready for planting will have a small swelling where the cotyledon is beginning to emerge. To reduce the chance of seed damage during planting, the seed must be planted before the cotyledon is ⅛-inch long. Oxygen deprivation may become a problem if the seed is allowed to grow too long while still in the bins.

Some growers store wild rice seed outdoors for the entire winter, but this is only possible in northeastern California at elevations above 4,000 feet. It is not recommended at lower elevations, as warm spring weather there would allow excessive seedling growth before planting time. Seed can be placed in plastic mesh bags for outdoor storage. The bags must be kept submerged in water, usually in water-filled pits. Storage should be deep enough to be below the winter ice depth and not allow mud to cover the seed. This method of storage is risky: there is a possibility that the seed will germinate before normal planting dates.

PHOTO: JACK KELLY CLARK

Figure 16. Wild rice curing in bins.

Planting wild rice

Growers should always check the wild rice seed in each bin for germination at least 2 weeks before the expected planting date. Normal germination rates are 70 percent and higher, but the actual germination rate may vary from 0 to 95 percent. To check, place a known number of seed into a pan of water or several 8-ounce cups at room temperature. Successfully germinated seed will develop a cotyledon longer than the seed in 14 days. Based on the germination rate, seeding rates should then be adjusted to provide a specific number of pure live seed (PLS) per square foot.

Most growers in California plant 100 to 150 pounds per acre of wild rice seed to ensure adequate population densities. This is about 7 to 11 PLS per square foot if the seed germination rate is 70 percent. Volunteer stands of 10 to 15 plants per square foot produce the highest wild rice yields in northeastern California by suppressing tillering to allow harvest of mostly primary tillers. Too dense a population of plants can increase the risks of lodging and nitrogen deficiency. Less-dense populations are less competitive with weeds and often have harvest timing problems because of asynchronous maturity between primary and secondary panicles.

Most wild rice in California is seeded into water by aircraft or ground equipment (crawler or steel-wheeled tractors with spin spreaders) in flooded basins. When seeded from the air, wild rice seed is diluted with grain (usually oats) at 2 parts grain to 1 part wild rice as a way to prevent bridging in the hopper of the airplane. Seed that are not covered by soil can be dislodged by water movement from waves or fluctuating water levels. To prevent this, a coarse seedbed is prepared with a chisel plow just before flooding and seeding so the soil will "melt" and cover the seed.

Dry seeding is another viable option, but the basin must be flooded immediately after planting to reduce the chance of desiccation. Seed moisture should not fall below 27 percent. In situations where individual basins cannot be flooded quickly, growers can fill a neighboring basin beyond its normal level to serve as a reservoir and then seed into dry soil in the dry basin before rapidly flooding it with water from the overfilled basin. By dry-seeding wild rice near sundown, growers can avoid exposing the seed to the drying effects of direct sunlight. If seed is to be spread on dry soil, a ring roller or harrow is often used to cover the seed with at least ½ to 1 inch of soil. Seedlings will emerge from soil depths of up to 2 inches.

Volunteer stands of wild rice in northeastern California require special management after harvest and in the spring. After harvest, the field is disked to incorporate any seed that remains in the field into the soil and prevent losses to desiccation and wildlife feeding. Often, basins are flooded all winter long to encourage the breakdown of crop residue for disease control and to convert (mineralize) organic matter N to NH_4^+-N. In February or March, growers check for seed germination and estimate potential stand density by sieving seed from the top 2 inches of soil using a screen. If the seed has germinated, it is best not to disturb the basins. If the wild rice has not germinated and the basins are flooded, growers use a spiked roller to uproot weeds. If the basins are not flooded, they use spring disking to incorporate fertilizer and control broad-leafed cattail (*Typha latifolia* L.). Growers who are doubtful of the potential success of volunteer stands may want to overseed the basin to ensure a good stand. The timing for overseeding should match the germination date for volunteer seed so the two crops will have similar maturity dates.

The chemistry of flooded soils

Flooding starts biological and chemical reactions that do not normally occur in well-aerated soils. Water displaces the air in the soil, transforming the root zone from an environment rich in oxygen *(aerobic)* to an environment lacking oxygen *(anaerobic).* Within a day of flooding, the entire plowed layer becomes anaerobic, with the exception of a thin aerobic or oxidized layer on the soil surface (figure 17). A dynamic balance between the rate at which oxygen is supplied through the water column and the rate at which oxygen is consumed in the soil determines the thickness of the aerobic layer. The aerobic layer of a mineral soil may be only ¼ to ½ inch thick and is usually brown as a result of the presence of oxidized forms of iron and, in some soils, manganese. Some flooded organic soils may not have a surface oxidized aerobic layer.

Conditions in the thin aerobic layer are similar to those in a well-drained soil, but conditions in the underlying anaerobic soil are different. Virtually no oxygen is present in the anaerobic

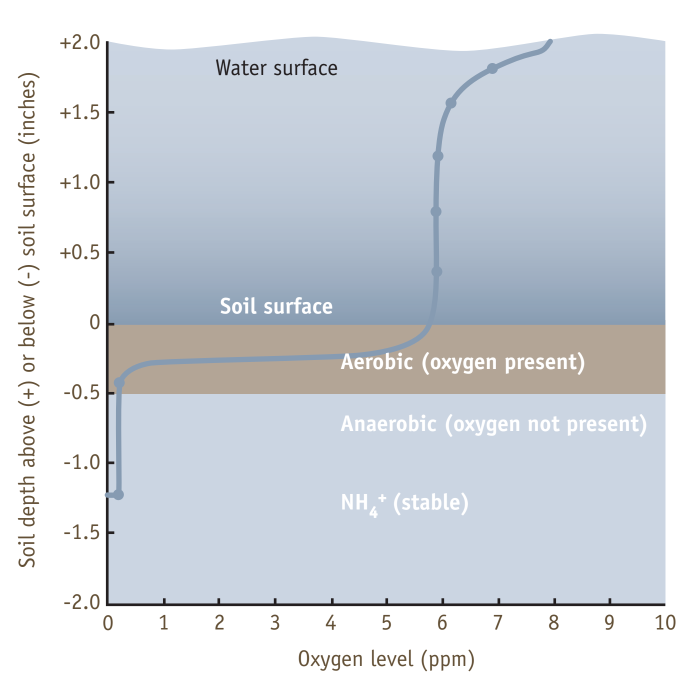


Figure 17. Oxygen concentration in a typical flooded basin.

layer, or *course*, and the soil is likely to be gray or grayish brown because the ferric form of iron has been reduced to the more soluble ferrous form and has subsequently precipitated as iron sulfide. The anaerobic soil conditions increase the availability of soil phosphorus (P) by converting ferric phosphate to the more-soluble ferrous form. After the oxygen is gone, any NO_3^--N is rapidly denitrified and lost to the atmosphere as nitrogen gas (N_2). NH_4^+-N, the N form utilized by wild rice, is highly stable in flooded soils because it cannot be nitrified to NO_3^--N in the absence of oxygen. If wild rice basins are drained and dried, though, NH_4^+-N will readily nitrify to NO_3^--N. Then, when the basins are flooded again, NO_3^--N is denitrified to N_2 gas.

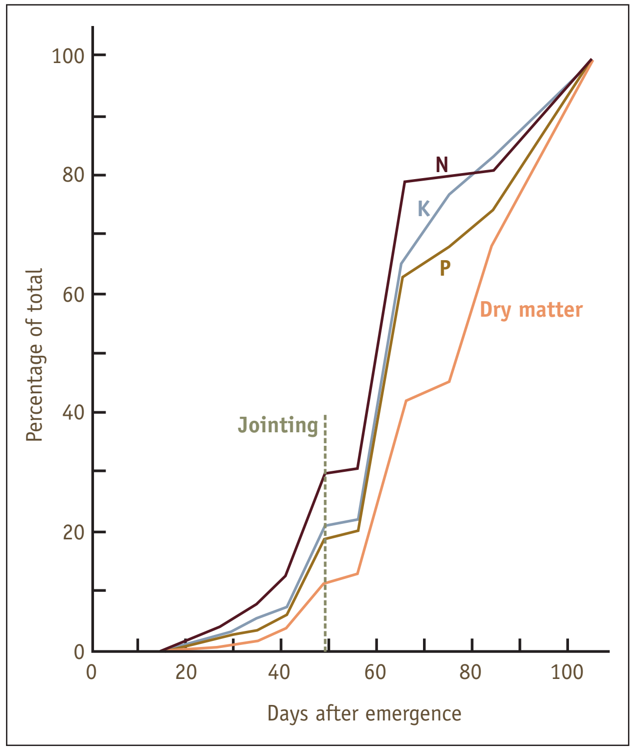


Figure 18. Accumulation of dry matter, N, P, and K in wild rice during the growing season.

Nutrition of the wild rice plant

Wild rice accumulates nutrients slowly during the early vegetative growth stages. Most growth and dry matter production occurs during the reproductive phase. Less than 12 percent of the total dry matter has been produced by the time the plant completes the jointing stage of growth. Thirty percent of dry matter production occurs over a 10-day period from boot stage to early flower stage. The remaining 50 percent of dry matter is produced during the last 30 days, from midflowering to maturity. Wild rice accumulates 70 percent of its total nitrogen during flowering and grain formation (figure 18).

The common nutrient deficiencies found in California wild rice are N and zinc (Zn). Plants lacking in N are lighter green and shorter than plants that receive sufficient N; the lower leaves of affected plants have yellow tips and margins. For wild rice production, N from organic matter is seldom adequate to provide economically viable yields.

The most efficient time to apply N is before planting. Growers estimate their preplant N rates based on their own experience and gain additional knowledge from current-season tissue samples for use next season. Too high an application of N causes excessive vegetative growth and lodging, so growers usually keep preplant N rates fairly conservative, knowing they can supplement N later on as a topdressing. The most common N practice is to incorporate 60 to 120 pounds of N per acre into the soil before flooding in the spring. Anhydrous ammonia (82% N), aqua ammonia (20% N), and granular urea (46% N) are common sources of preplant N. Organic-approved chicken manure (approximately 6% N) can be spread and incorporated for organic production of wild rice. It is important that all N fertilizer be incorporated at least 4 inches deep into the anaerobic soil layer so it will remain in the stable NH_4^+-N form.

As the plants reach the aerial growth stage, a grower can assess the need for surface-applied (topdressed) N by taking tissue samples and looking for >>4.0 percent total N in the first aerial leaves and >>3.0 percent N at boot stage. Because N tissue levels change quickly over time, it is important to sample tissue early in the aerial stage and again at the boot stage to confirm the need for topdressing.

Proper application timing is critical to making sure the crop gets the most out of the topdressed N. Nitrogen losses from volatilization of topdressed NH_4^+-N fertilizers are affected by water pH and temperature: volatilization losses increase tenfold with each 1.0 increase in water pH and they roughly double with each 18°F increase in temperature. Hydrolytic conversion of urea to NH_4^+-N is about 66 percent after 1 day and 100 percent after a week, and conversion of all of the ammonium sulfate (21% N) takes place within minutes. Typical application rates for topdressing are 100 to 150 pounds of material per acre (46 to 69 pounds of N per acre for urea or 21 to 32 pounds of N per acre for ammonium sulfate). Although ammonium sulfate becomes available as N a little more quickly, urea is often less costly to purchase and apply because aerial application costs usually involve a weight cost factor. Organic topdressing options include materials containing sodium nitrate (up to 16% N). Application timing for topdressed N should match the high N demand of the reproductive growth phase. Single topdressings are usually applied as the panicles emerge; two topdressings are commonly split between the boot and flowering growth stages.

Plants lacking in Zn appear stunted. The potential for Zn deficiency in wild rice is best assessed through soil testing. Soil samples should be analyzed for Zn using the DTPA test. If the soil test results show less than 0.5 ppm, apply 5 to 10 pounds of Zn per acre (14 to 28 pounds of $ZnSO_4$ per acre or equivalent) to the soil surface at planting or flooding time so it will be in the aerobic layer near the shallow roots for maximum plant availability. Organic production systems can use approved Zn products. Topdressing with Zn is not recommended for wild rice, since Zn deficiency often begins at the seedling stage.

Phosphorus fertilizer should be incorporated into the soil, since surface application of P fertilizer can aggravate algae problems. The highest risk of water quality degradation is found over organic soils that retain low amounts of phosphate. One way to reduce the risk of pollution from P fertilizer is to recycle drain water or route drain water through a grassy area that can trap sediment and nutrients.

Wild rice is a salt-sensitive crop with a threshold of yield reduction at water and soil EC values ranging from 2 to 3 dS/m. It may be possible to drain affected basins and apply gypsum or sulfur (elemental S, or sulfuric acid if lime is present) to help reclaim salt-affected areas within a wild rice basin. When high rates of sulfur are applied to the soil and the basins are flooded, though, the sulfur can be reduced to toxic sulfide gas in the anaerobic soils. If the salt-affected portions of a wild rice basin are large, the grower should grow salt tolerant crops instead of wild rice for the time being, and the site should be reevaluated for wild rice production suitability.

Weed management

Weeds in wild rice are usually controlled by a combination of methods. Deep water is the best long-term control for weeds in wild rice. Plant weed-free seed to avoid introducing weeds and use dense wild rice stands that will successfully compete with weeds. Fallowing land for a year or periodically planting an alternative crop helps control weeds. Glyphosate may be used to control weeds after harvest or while the basin is fallow. On levees, mow or suppress weed growth with herbicides to create safe traffic pathways and reduce habitat for burrowing rodents such as muskrats and gophers. A description of the most common weeds found in wild rice basins follows.

Common waterplantain (*Alisma plantago-aquatica* L.) is an immersed, erect, aquatic perennial that reproduces from seed and perennial rootstocks (corms). Seeds are round, reddish brown, and ⅛ inch in diameter, and they remain viable in the soil for many years. Waterplantain seeds continue to geminate throughout much of the growing season. The plant may grow 48 inches tall and has elliptical leaf blades 10 inches long and 6 inches wide. The leaves have long petioles. Experiments have shown that a single waterplantain plant per square foot could cause a wild rice yield loss of 43 percent. Cultural management practices that create dense, vigorous wild rice stands help wild rice to compete successfully with plantain. First-year waterplantain seedlings can be controlled with herbicide applications. The greatest competition, however, comes early in the season from second-year plants during the first 8 weeks of flooding if the basin water is less than 6 inches deep (figure 19). In northeastern California, fall herbicide treatments that follow harvest and winter flooding can reduce second-year waterplantain populations somewhat.

PHOTO: JACK KELLY CLARK

Figure 19. Common waterplantain (*Alisma* sp.) competing with wild rice.

PHOTO: JACK KELLY CLARK

Figure 20. Cattail (*Typha* sp.) colony competing with wild rice.

Broadleaf cattail grows in shallow water and areas with poor drainage. Plants are 4 to 8 feet tall and usually grow in colonies. Cattails are perennial weeds that reproduce by rootstocks (rhizomes) and by minute airborne seeds that germinate readily in mud and shallow water. The seeds remain viable in soil for more than 5 years. An established plant has an extensive rhizome system and erect stem with long, narrow leaves. The flowers take the form of a long, cylindrical spike at the end of the stem. New infestations of solitary plants (figure 20) may be successfully eliminated by hand roguing. The most widely used control method for cattails is spring disking, which cuts the rhizomes, exhausting root reserves. Repeated cutting of plants below the water level can control individual plants since cattails need oxygen from their aerial leaves for respiration, but this usually is only partially successful at best and is not a widespread practice because of its high labor cost.

Common arrowhead (*Sagittaria latifolia* Willd.) is a rooted aquatic perennial weed with arrow-shaped leaves that reproduces by seeds and specialized storage roots (tubers). The lower leaves are all basal with petioles as long as the water is deep. Plants are 1 to 2 feet tall with white flowers. The seeds are flat, ⅛ inch wide with marginal wings, and are clustered into a spherical head. The weed grows in shallow water and usually is not a serious problem in wild rice.

Algae damages wild rice plants by forming a mat on the water surface over wild rice plants before emergence. The greatest injury is caused when the algae prevents the emerging seedlings from reaching the floating leaf stage. An early application of copper sulfate when seedlings have only one or two leaves is the preferred treatment. Keeping the water moving through basins can also reduce algae damage. Growers sometimes use a garden-type hand-held fertilizer spreader to treat trouble spots, such as corners of basins where water movement is slow and algae damage is often more severe. Placing mesh bags that contain coarse (rock) copper sulfate in weirs to dissolve in flowing water is *not* recommended because of distribution problems within the slow-moving water. Most algae can be controlled with 2.4 pounds of copper sulfate per acre-foot of water (about 1 ppm). If the water is hard it will require more copper sulfate to control the algae; application rates of up to 15 pounds of copper sulfate per acre are common. Copper sulfate will not provide good control of blue-green algae.

Insect management

Rice leafminer (*Hydrellia griseola* Fallen) is a small, olive-green fly. Leafminers prefer to lay their eggs on floating leaves because the eggs require high levels of humidity for survival and hatching. The larvae burrow within the floating leaf and consume the center of the leaf (mesophyll). Leafminers usually are not an economically important problem.

Rice water weevil *(Lissorhoptrus oryzophilus)* can be a pest of wild rice in the Sacramento Valley. The adults infest wild rice basins from mid-April to mid-June. They feed on emerged wild rice leaves, causing longitudinal scars on the leaves that do not result in any economic loss. Females deposit eggs in the leaf sheaths and the resulting larvae feed on the roots of the plant. Significant root damage can cause stunting and yield reductions. Some control can be achieved by adjusting planting dates; early-planted basins escape damage because the plants will be established before the weevils can do any harm, and late-planted basins can also avoid infestation.

Midges, if their numbers are large, can damage wild rice in northeastern California. The *Chironomid* adult is a small, delicate, mosquito-like fly. It lacks scales on its wings and does not have functional mouthparts. Adults are non-biting and usually are inconspicuous unless there are enough to form a "cloud." The adults usually come from wet areas adjacent to wild rice basins and lay their eggs in newly flooded wild rice basins. To check for larvae (figure 21), slide a mud-coated leaf between two fingers. The larvae feed on algae and damage plants by abrading leaf margins. Normally, wild rice plants will outgrow midge damage by producing new leaves that are larger and so less susceptible to damage as the midge hatching period progresses. Economic damage is more common in first-year basins, where the wild rice stand is often thin. Midge control is commonly achieved with an application of insecticide or *Bacillus thuringiensis israeliensis* (BTI). In severe cases of midge damage, a grower can drop the level of water in the basin as an emergency measure. Second-year and older volunteer wild rice stands in northeastern California can host enormous numbers of midge larvae, but plant populations usually are high enough to make control unnecessary.

PHOTO: JACK KELLY CLARK

Figure 21. A *chronomid* midge and damaged wild rice leaf.

Bird pest management

Cowbirds and Blackbirds (Brewers, Yellowhead, and Redwing Blackbirds) cause the most bird damage to wild rice. Wild rice is a preferred food and habitat for blackbirds, but we know little about what exactly makes wild rice basins so attractive to them. Most blackbird damage takes the form of an increase in shattering, although their feeding also damages the crop. Blackbird depredation on wild rice begins when the first kernels are in the milk stage. Blackbirds do not consume the entire seed at this stage; rather, they squeeze the hulls and force the soft kernel out through the split between the hulls. As the wild rice kernels mature and turn dark, the blackbirds separate the hull and awn from the seed and eat the entire seed. Crop losses of 10 percent and more are common. Little is known about where the damaging blackbirds come from, that is, whether they are migratory or resident. Blackbirds will nest in basins, and they generally cause more damage when there is suitable vegetation for habitat in nearby ditches and ponds.

The most successful control method for blackbirds is trapping. The USDA Wildlife Services animal damage control program has designed a successful trap for depredating birds. Traps should be kept supplied with food and water until the birds can be sorted to remove protected species and humanely euthanize other species with carbon dioxide. Other methods for blackbird management include the periodic patrol of basins at irregular times during the morning and evening and the use of shotguns and cracker shells to scare birds. Some growers successfully move or "herd" birds away from basins with commercial spray planes, ultralight aircraft, or power parachutes, but the birds will quickly return if no alternative feeding and roosting areas are available.

Geese and ducks damage wild rice by feeding on young plants in the floating leaf stage. Propane cannons will provide some control, but at least one is needed per basin to achieve measurable control. Roving patrols with shotguns loaded with cracker shells can reinforce the effectiveness of propane cannons.

In northeastern California, growers rely upon the survival of unharvested wild rice left in the field to volunteer the next season's crop, and birds' feeding after harvest threatens volunteer stands. Stand damage is most severe if growers do not disk the basins after harvest and if they flood the basins during winter, a practice that encourages bird use of the fields. By not flooding fields in the winter, a grower can reduce waterfowl activity there. To reduce the loss of seed to birds, growers can roll their fields after harvest to facilitate drying and then disk seed deep enough to be beyond the reach of birds. In spring, the fields are dried and disked to bring seed to within 2 inches of the surface.

Disease management

Wild rice diseases in California are localized problems. The following pathogens have been demonstrated to be present in wild rice in California.

Brown spot disease can affect all varieties of wild rice at every stage of growth. Brown spot is actually two distinct diseases. One, caused by *Bipolaris oryza,* is called "fungal brown spot"; the other, caused by *B. sorokiniana,* is called "spot blotch." Fungal brown spot lesions are oval, uniform, evenly distributed, and approximately the size and shape of sesame seeds. The spots are dark brown with yellow margins, and some have a light center. Spot blotch usually does not have a halo and the larger lesions are often more irregular in shape. Both diseases occur in California, but the state's dry climate keeps damage low. The occasional infections that do occur are seen in dense stands late in the season when heavy dews are more prevalent. The disease is also a greater problem in locations where wild rice has been continually produced for a number of years. Crop rotation can help reduce the inoculum.

Red root of wild rice is caused by *Pythium torulosum.* Little is known about the disease, which appears to cause problems only in northeastern California. The fungus colonizes the primary root of wild rice seedlings, turning it brick red (figure 22). Secondary roots may be colonized, but surviving roots are usually white. The disease causes seedling death and is often associated with other conditions that weaken seedlings, such as cloudy water or midge feeding. Poor seed germination and low seed vigor are often confused with red root or may be associated with the disease. Basins with severe losses to red root can in many cases be replanted with viable seed if there is enough time left in the growing season to produce a crop.

Phytophthora root and crown rot of wild rice is caused by *Phytophthora erythroseptica.* The disease has been found in both the Sacramento Valley and northeastern California. Individual plants collapse as the fungus colonizes their main stem vascular tissues (figure 23). At one time the disease caused the loss of entire basins, but it is generally tolerated today as a cause of stand thinning. Basins that share a common water system often have similar incidences of the disease. Crop rotation may reduce occurrence of the disease.

Stem rot of wild rice is caused by *Sclerotium oryzae.* This disease begins when small, hard, black fungal bodies (sclerotia) floating in the water infect plants at the water level. The fungus creates lesions at the water level and these expand and weaken the stems, causing early death of plants and lodging at harvest. Sclerotia are produced in large numbers on infected stems at the end of the season, particularly after harvest. Dense stands and excessive N applications enhance the disease. Control consists of the incorporation of plant residues immediately after harvest to reduce the production of sclerotia on plant tissue. Infected fields should be rotated to nonflood crops for more than 1 year to help reduce sclerotia numbers. There are no wild rice varieties known to be resistant to stem rot.

PHOTO: JACK KELLY CLARK

Figure 22. Red root of wild rice caused by *Pythium torulosum*.

PHOTO: JACK KELLY CLARK

Figure 23. Phytophthora root and crown rot of wild rice caused by *Phytophthora erythroseptica*.

Harvesting wild rice in California

Growers estimate a wild rice crop's appropriate time to harvest by visually examining mature heads and directly measuring the moisture percentage of the kernels. Wild rice should be harvested when grain in the primary panicles is dark colored and shattering can be easily induced by lightly touching the panicle. Generally, growers should harvest as soon as the crop matures since, once mature, shattering losses can occur quickly and in a brief period of time, sometimes within a day or two. Fields may also require early harvesting if there is a limited number of combines available, adverse weather is imminent, or blackbirds are threatening the crop.

To measure moisture levels, the grower samples five to ten pistillate portions from primary panicles, separates the grain by rubbing, grinds the grain in a coffee grinder, and measures the percent moisture of the resulting ground grain with a moisture meter. As the grain matures, the kernels will turn brown-black and the moisture content will drop from 40 percent to less than 30 percent. Wild rice is ready for harvest when seed moisture declines to near 32 percent. Shattering risk increases dramatically when moisture levels drop below 30 percent.

Wild rice that has been harvested but not yet processed is termed *unfinished* or *green.* Wild rice yields of California varieties commonly reach 1,500 to 2,000 pounds per acre. Still, 500 to 1,500 pounds or more of mature seed per acre from all varieties falls to the ground before and during harvest. After processing, the final wild rice product is termed *finished*; finished wild rice yields are about one-half of the harvest weight. *Recovery* is the ratio of finished to unfinished wild rice and is usually in the range of 40 to 55 percent. Lower recovery values may indicate that the crop was harvested too early when the grain was not yet mature or that the combine needs adjustment to improve grain-chaff separation. Conversely, higher recovery values may indicate harvest of a mature crop close to shattering, in which case the combine settings are adjusted to remove greener seeds that will never become finished wild rice. Growers usually sell the crop in unfinished form. Final crop payments are usually based on the weight of the finished crop minus a fee for processing the unfinished material.

Most growers use an axial flow combine to harvest wild rice. The wild rice industry has adopted rice combine technology including combine modifications such as grain divide points, draper systems, and support systems. These advances in technology have made harvesting more efficient.

Growers prefer large-diameter combine reels up to 7 feet in diameter to permit the reel bats to enter the crop without pushing the plants forward, but these are unnecessary if reel arms are long enough to reach out over the crop. The reel's peripheral speed should be sufficient to control the crop and press it slightly to the rear. The height of the reel should be adjusted to sweep the crop back into the draper (moving belt) extension. The plants should be cut low enough to allow harvest of most of the grain but high enough to keep the amount of straw going into the combine down. If the crop is lodged excessively, a bow-type divider is used in place of standard harpoon-like dividers to depress the crop at the end of the sickle.

The combine cylinder brings the grain into contact with a concave surface where the seed is separated from the panicle. The cylinder's speed and proximity to the concave surface should be enough to thresh the kernels without causing excessive damage to the straw or grain. Typical combine settings include a large concave separation and slow cylinder speed to reduce kernel breakage since the grain is easily separated from the head. Large quantities of broken straw decrease the capability of the walkers and sieves to separate the grain from the straw. The right adjustment of air settings is critical for proper separation of grain and straw on the sieves. Too much air will blow the lighter kernels out the rear of the machine, whereas too little air will permit too much light, chaffy material to accumulate with the clean grain. Set the sieve and air adjustments to minimize the amount of tailings return material. Check the air passages frequently; light material (unfilled kernels, male florets, etc.) may accumulate and cause plugging.

The combine's support system has to have a large track surface so it will be able to work reliably under the extremely soft soil conditions that exist in the fields at harvest time. Support systems range from conventional half-tracks and guide wheels to full-track systems with pads bolted to each track shoe. The best situation for a grower is to have access to both full-track and half-track machines, since each offers advantages and disadvantages depending on the harvest situation.

Processing wild rice in California

Nearly all of the wild rice grown in California is processed in the state, but sometimes at the height of the harvest season that processing capacity is exceeded and wild rice is shipped to Minnesota for processing. The major steps in the processing of wild rice are separation of immature kernels, aging, parching, dehulling, scarification, cleaning, grading, and packaging. The equipment and techniques used vary from one processing plant to the next.

When unfinished wild rice is delivered to a processing plant, a separator may be used to remove immature kernels and so improve overall processing efficiency. The separator uses air currents and a slotted screen to separate the unfinished wild rice from other combine waste. Combine-run grain is moved by gravity across a vibrating tray and into a cylinder where air suction removes chaff and other light materials. Next, to remove large materials, the grain is allowed to fall through a slotted screen. Use of a separator reduces processing costs by eliminating waste material, including weeds and weed seeds, from the volume of material that actually goes through the processing plant. In California, though, most growers just adjust the combine to harvest a higher percentage of mature wild rice kernels to eliminate the need for a separator.

Aging (often called *curing*) is a chemical and biological process that involves a large number of microorganisms, respiration, heat, and moisture management. Aging takes place in either 4-by-4-foot steel bins or in bottom-dump aluminum trailers (figure 24) over a period of 4 to 7 days. After harvest, the bins are weighed and then periodically flooded to reduce the risk of damage from heat caused by plant and microbe respiration. Wild rice that is aged in bottom-dump trailers is periodically transferred between trailers to prevent prolonged exposure to high temperatures. Wild rice processors consider aging to be necessary for color development, flavor enhancement, and hull degradation. Immature kernels, originally greenish in color, change to brown during the aging process. The flavor is slightly altered; some consumers like this.

PHOTO: JACK KELLY CLARK

Figure 24. Monitoring temperatures of wild rice curing in bottom-dump trailers.

If aging is done incorrectly, though, off-flavors can develop. Another result of aging is hull degradation, which makes for more efficient dehulling.

Wild rice is processed by two methods in California. The first is the traditional batch rotary parcher, also called a drum parcher. The parcher consists of a drum supported on rollers to permit continuous full rotation (figure 25). Propane gas burners underneath the drum heat its exterior surface. The interior surface of the drum may reach temperatures of up to 280°F. The moisture content of wild rice after aging is approximately 40 to 45 percent. During parching, the grain is heated to gelatinize starches and then dried to a moisture content of 7 to 11 percent. It is important to achieve a high degree of gelatinization in the wild rice. Parching is complete when the white center of the kernels turns dark and glassy-looking. Most processors operate the parcher in a way that gives the wild rice a slightly toasted flavor. Parching causes the kernels to shrink, and that loosens the hull. After parching, the wild rice is passed over a cleaning screen to remove stalk fragments or other debris that may be present. Various types of suction devices are employed throughout the processing line to remove wild rice fragments and dust contaminants. About 500 pounds of unfinished wild rice goes into each parcher, where it is heated while the temperature is monitored with an infrared thermometer (figure 26). When the temperature reaches 212°F, a loose lid is fitted onto the parcher to retain heat and slow moisture loss. The infrared thermometer is used to measure final temperature (and, indirectly, final moisture content) before the parcher is emptied. If moisture levels fall below 10 percent, a higher number of kernel cracks will occur at the hulling stage. The entire parching process takes about 2½ hours per batch.

The second processing method, parboiling, is used for over two-thirds of the California wild rice crop. This technique allows continuous heating and drying and can efficiently process large volumes of wild rice (figure 27). The wild rice is introduced into a chamber where pressurized steam accomplishes the same gelatinization process achieved by the drum parchers. Immediately after parboiling, the wild rice is dried in a large rotary drum. Parboiling is considered superior to drum parching for producing product with a low bacterial count, but drum parching remains in use as a traditional method for processing wild rice.

Hulling should immediately follow parching to keep the development of cracks in the wild rice to a minimum. Cracks often result in broken kernels, leading to a reduction in crop value and greater variability in cooking time. Two types of huller are available to processors. The *double-roll huller* is the more common. In a double-roll huller, wild rice kernels fall between two closely spaced, rubber-covered rollers that roll at different speeds and so impart a rubbing action to the kernels. The *barrel huller* is an enclosed drum with rotating paddles that remove the hulls. Hulls have a low economic value and are either burned to generate electricity or used as a soil amendment.

Figure 25. Wild rice drum parchers.

Figure 26. Using an infrared gun to monitor parching temperatures.

PHOTO: JACK KELLY CLARK

Figure 27. Wild rice exits the steam parboiler.

Scarification removes a portion of the outer layer of the kernel. Wild rice that will be used as an ingredient in prepared products is scarified to give it a uniform, reduced cooking time that is particularly beneficial when it is mixed with conventional rice. Wild rice that is sold as a pure, packaged product is seldom scarified, as the process sometimes creates a light-colored grain. The typical scarifier consists of a slanted cylindrical container with a shaft extending longitudinally inside, with several rubber paddles attached. The slope of the scarifier, shaft speed, and clearance of the rubber paddles control the degree of scarification.

Grading of the finished wild rice kernels varies among different processing plants and marketing organizations. Graders sort for both length and width. Although Califronia wild rice seed standards were adopted in 1997, processors grade wild rice to classifications set by customers, which are not yet standardized. Short kernels and broken kernels are classified as *brokens*. The A, B, and C grades are classified primarily by kernel width.

Grade A wild rice is often sold as a pure packaged product since there is a consumer demand for it. The B and C grade kernels normally are sold in bulk as an ingredient because they have shorter, more uniform cooking times; these grades usually are scarified. The broken kernels are used for soups, wild rice flour, and chips.

The gravity separator sorts out unhulled kernels and small rocks. The unhulled kernels return to the huller for another pass through the processing equipment. A de-stoner separates large-diameter wild rice kernels from rocks. The de-stoner is similar to a gravity separator, but it uses higher volumes of air to separate materials. Glass is strictly prohibited from the processing facility since pieces of glass are difficult to remove. Growers prohibit employees from using glass containers anywhere on a wild rice farm.

Marketing California wild rice

The cultivation of wild rice has brought this crop in a stable supply to the marketplace. Traditionally served with wild game, wild rice was an expensive gourmet food back when it was harvested exclusively from natural stands in Minnesota and Canadian lakes, because of highly variable yields. Changing American food habits have made wild rice an important ingredient in many prepared food products; more than 70 percent of the wild rice produced is sold to marketers as an ingredient in prepared or packaged foods or in blends with other grain products.

Wild rice is available for sale in a variety of package units and products. Paper or plastic 50-pound bags and large fiber tote bags containing 2,000 pounds of wild rice are used for industrial sales. Plastic pails containing 25 pounds of wild rice are popular for restaurant sales, and smaller, 1-pound or 8-ounce packages are used for retail sales. Other wild rice products include a precooked, ready-to-microwave product and wild rice chips. There has been extensive activity in the development and publication of recipes for wild rice.

Wild rice is comparable in nutritive value to other common cereals, but its protein percentage is high and its fat percentage is low. The amino acid composition of wild rice protein is similar to that of oats. The crude fiber percentage is similar to that of rice and oats, but is half that of wheat and corn. The total carbohydrate percentage of wild rice is similar to that of other grains except for rice, which has a slightly higher percentage. Processed wild rice is an excellent source of the B vitamins and it is especially rich in riboflavin.

The California Wild Rice Program was established in 1986 to support wild rice promotion and research. A California marketing order, the program must be renewed by election every 5 years. All growers participate by paying an acreage assessment ($8.00 per acre in 2005). Research program topics have included variety testing, fertilizer management, blackbird control, weed control, and seed studies. Promotion efforts have included the development of recipes, chef tours, cooking schools, demonstrations, and newspaper, magazine, and television advertisements. The California Wild Rice Program has supported federal and state export promotion programs, including efforts to promote wild rice sales in Europe. The California Wild Rice Program is also empowered to set standards and grades and to control the wild rice supply flow to market, but it has not yet exercised these authorities. Information about wild rice, including recipes, is available from the office of the California Wild Rice Program, online at http://www.cawild rice.com/.

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