Louisiana Rice Production Handbook

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Glossary
Foreword
Clayton A. Hollier

Rice has been produced in Louisiana since the early 1700s. Not only have the methods of growing rice changed dramatically in the last 300 years, but also the systems by which we share information about rice production. Although there are other methods of disseminating information, for years extension and research publications have addressed specific aspects of rice production in the state. In the 1980s several faculty members in the Louisiana State University Agricultural Center recognized that a comprehensive, one-volume publication was needed to advise extension agents, agribusiness dealers, consultants and any other rice industry representatives about rice production in Louisiana. That Rice Production Handbook, published in 1987, was not intended to replace other LSU Agricultural Center publications, but to enhance existing and future rice publications written by the LSU Agricultural Center faculty.

The current volume, in many ways, is not a revision of the 1987 publication although some portions of the original version have been revised. The Louisiana Rice Production Handbook is, in reality, a new publication encompassing the technology and knowledge of today that will help the rice industry of Louisiana flourish in the next millennium.

I thank all of those who supported this effort, especially the authors of the various sections and the reviewers of the entire publication. Their many hours of dedication, advice and encouragement are appreciated more than can be expressed here. Also, thank you to all who provided the slides for the photographs. Photographs express in many ways what words cannot.

Introduction
Steven D. Linscombe

French explorers led by Bienville first introduced rice into Louisiana in 1718. The production of rice was limited for the next 150 years. It was grown mainly in small plots along the Mississippi River as food for laborers and low income farmers. Production increased rapidly after the Civil War. The total crop increased from 1.6 million pounds in 1864 to 9.5 million pounds four years later. Production reached 22 million pounds by 1874 and doubled in the next three years.

In 1884, a visiting farmer from Iowa discovered that rice could be produced on the broad flat prairie lands of southwest Louisiana by using mechanized methods then used to produce wheat in the upper Mississippi Valley. This led to a major expansion of rice production.

Production has expanded to other areas of Louisiana, especially the northeastern portion. Rice continues to be an important agronomic crop in southwestern Louisiana also. Rice acreage has fluctuated in Louisiana in recent years from a high of 620,000 acres in 1994 to a low of 518,000 acres in 1991. Much of this fluctuation has been caused by farm policy programs and world market economics.

Rice will continue to be important to Louisiana agriculture. With this in mind, LSU Agricultural Center scientists who work in various aspects of rice production and economics in Louisiana have written this publication to help Louisiana producers increase yields while holding down costs and thus increase their profits.

The information incorporates the latest findings from extensive rice research and extension programs conducted in Louisiana by the LSU Agricultural Center. Much of this work is funded at least partially by the state’s rice producers through check-off funds administered by the Louisiana Rice Research Board.
Site Selection
Because rice is grown under flooded conditions, it is best produced on land that is nearly level, minimizing the number of water retaining barriers or levees required. Some slope is required to facilitate adequate drainage. Generally, slopes of less than 1 percent are necessary for adequate water management. Most of Louisiana’s rice-growing areas are well suited for rice production with a minimum of land forming. Recent innovations using laser systems have made precision leveled or graded fields physically and economically feasible.

Precision grading of fields to a slope of 0.2 foot or less change in elevation between levees is important in rice production for the following reasons: (1) permits uniform flood depth, (2) may eliminate a large number of levees, (3) facilitates rapid irrigation and drainage, (4) can lead to the use of straight, parallel levees which will increase machine efficiency, (5) eliminates knolls and potholes which may cause delay of flood or less than optimum weed control and (6) reduces the total amount of water necessary for irrigation.

Previous cropping history is important when selecting fields. Some herbicides used on rotation crops may persist in the soil and injure rice planted the next year. Some herbicide labels may preclude growing rice the year after that herbicide is used.

Soils
Rice can be grown successfully on many different soil textures throughout Louisiana. Most rice is grown on the silt loam soils derived from either loess or old alluvium, which predominate the southwestern region, and, to a lesser extent, the Macon Ridge area of northeast Louisiana. The clay soils in the northeastern and central areas derived from more recent alluvial deposits are also well adapted to rice culture. Deep sandy soils are usually not suitable for rice production. An important factor, regardless of soil texture, is the presence of an impervious subsoil layer in the form of a fragipan, claypan or massive clay horizon that minimizes the percolation of irrigation water, making it possible to hold water in rice paddies which are, in essence, shallow ponds.

Water Requirements
The ability to achieve optimum water management is essential in attempting to maximize rice yields. In general, pumping capabilities are adequate if a field can be flushed in two to four days, flooded in four to five days, and drained, dried and reflooded in two weeks. This is much easier on fields that have been uniformly leveled to a slope of no more than 0.2 foot fall between levees.

Planting Dates
The optimum seeding dates will vary by location as well as from year to year because of variation in environmental conditions. Rice yields may be reduced by planting too early or too late. Average daily temperature at seeding is important in stand establishment. At or below 50 degrees F, little or no rice seed germination occurs. From 50 degrees to 55 degrees F, germination increases but not to any great extent until above 60 degrees F. Plant survival is not satisfactory until the average daily temperature is above 65 degrees F.

Based on this information and seeding date research, the following dates of seeding recommendations are made:

Southwest Louisiana - March 20 - April 30
North Louisiana - April 10 - May 15

Extremely early seeding can lead to a number of problems including (1) slow emergence and poor growth under colder conditions because of the inherent lack of seedling vigor and cold tolerance in many varieties, (2) increased damage from
seedling diseases (predominantly water mold) under cool conditions, (3) increased damage from birds (blackbirds, ducks and geese) which are more numerous in the early spring and (4) decreased activity of some herbicides.

While later seeding may avoid some problems associated with very early planting, delays much beyond the optimum planting dates usually result in other problems. In general, excessively late planting results in lower yields, increased disease and insect pressure, and poorer grain quality at harvest.

**Seeding Rates**

The establishment of a satisfactory plant population is an essential first step in successful rice production. When compared to other crops such as corn and soybeans, the emergence rate of rice is quite low, ranging from 50 percent to 60 percent. This is especially true in water seeding and reduced tillage systems. Seeding rates have been determined by researchers with these factors taken into consideration.

Rice in Louisiana is planted using three basic methods: water seeding (dry or presprouted seed dropped into a flooded field), drill seeding (planting with a drill on 7- to 10-inch drill spacing) and dry broadcasting (dry seed applied to a drained or dry field by either ground equipment or airplane).

Regardless of the seeding system used, the desired plant stand is constant. The optimum stand is 15-20 plants per square foot; the minimum stand is eight plants per square foot and the maximum stand is about 30 plants per square foot. Like most grasses, rice has the ability to tiller or stool and produce several panicle-bearing stems from one plant. This ability to compensate accounts for successful grain production from as few as eight seedlings per square foot, provided proper cultural practices are used and growing conditions are good. Stands also can be too dense. Excessive plant populations can often lead to reduced tiller production, more severe disease pressure and spindly plants that may be more susceptible to lodging.

Experimental results and commercial experience have shown that higher seeding rates are required when broadcast seeding than drilling rice. Water seeding or dry broadcasting requires 120-150 pounds of seed per acre. Drill seeding requires 90-110 pounds of seed per acre. Within each category is a range of planting rates to allow for some adjustment. The higher seeding rates should be used when planting under less than optimum conditions. Examples of circumstances when the higher seeding rate should be used include:

(a) Use higher recommended seeding rates when planting early in the season when there is potential for unfavorably cool growing conditions. Cool conditions will favor water mold (seedling disease) in water-seeded rice. This can reduce stands. Varieties also differ in tolerance to cool growing conditions in the seedling stage.

(b) Varieties differ considerably in average seed weight. Thus, a variety with a lower average seed weight will have more seed per pound. Table 1 shows seed weight per pound and the average number of seed per square foot at several seeding rates for most of the varieties. Producers may want to adjust seeding rates for this factor.

(c) Where seed depredation by blackbirds is potentially high, use a higher seeding rate.

(d) Where seedbed preparation is difficult and a less than optimum seedbed is prepared, use a higher seeding rate.

(e) If it is necessary to use seed of low germination percentage, compensate with seeding rates. Always use high germination, certified seed if possible.

(f) When water seeding into stale or no-till seedbeds with excessive vegetation, use higher seeding rates.

(g) If any other factor exists which may cause stand establishment problems (such as slow flushing capability or saltwater problems), consider it when selecting a seeding rate.
Dry Seeding, Fertilization Timing and Water Management

Dry seeding is the predominant method of seeding used in the north Louisiana rice-growing areas. Dry seeding normally works best on those soils where a well-prepared seedbed is practical and where red rice is not a severe problem. Rice can be dry-seeded using either a grain drill or by broadcasting.

When rice is to be drill seeded, a well-prepared, weed-free seedbed is desirable. A well-prepared seedbed will facilitate uniform seeding depth. This is important in establishing a uniform stand. Depth of seeding is important with all varieties, but is critical with semidwarf varieties. The semidwarfs are inherently slower in development during the seedling stage, and the mesocotyl length is shorter than in taller varieties. Therefore, semidwarfs should be seeded no deeper than 1 inch to maximize uniform stand establishment. The taller varieties may be planted somewhat deeper, but avoid seeding depths of more than 2 inches with any variety.

Where soil moisture is adequate, a flush may not be necessary. But, when soil moisture is insufficient and rainfall is not imminent, the field should be flushed within four days after seeding to assure uniform emergence. This necessitates having levees constructed and butted at or soon after seeding.

Rice can be broadcast on a dry seedbed using either ground or aerial equipment. Seed should be covered using a harrow or similar implement. Uniformity of seeding depth is much more difficult using this system. As with drill seeding, an immediate flush may facilitate uniform stand establishment.

Fertilization timing and water management are similar for both drill-seeded and broadcast dry rice. Phosphorus, potassium and micronutrient fertilizers should be preplant incorporated based on soil test results. The addition of 15 to 20 pounds of preplant nitrogen will ensure against nitrogen deficiency in seedling rice and is generally recommended. Avoid large amounts of preplant nitrogen in a dry-seeded system since wetting and drying cycles before the permanent flood can lead to loss of much of this nitrogen. Most of the nitrogen should be applied to a dry soil surface within five days of permanently flooding the field. If the precise nitrogen requirement is known, if the permanent flood will be maintained, and if the field will not be allowed to dry until maturity, all of the nitrogen can be applied ahead of the permanent flood.

When the required nitrogen rate is not known, or the field will be drained before harvest for any reason, apply about 70 percent of the estimated requirement at this time. Additional nitrogen should be applied at mid season. Large amounts of nitrogen should not be applied into the flood on seedling rice because it is subject to loss. With this system, the permanent flood should be applied as soon as possible without submerging the rice plants. This will normally be at the 4 to 5 leaf stage in fairly level fields. Delaying permanent flood with the intention of reducing irrigation costs may increase other production costs, reduce yields and decrease profits. Additional information on fertilizer timing in relation to water management can be found in the Rice Soils, Plant Nutrition and Fertilization section.

Water Seeding, Fertilizer Timing and Water Management

Water seeding is the predominant method of rice seeding used in Louisiana. It is widely used in southwest Louisiana and, to a lesser extent, in the northern portion of the state.

The use of a water seeding system can provide an excellent cultural method of red rice suppression and is the primary reason for the popularity of this system in south Louisiana. Rice farmers who raise crawfish in rice fields use water seeding because it is easily adapted to the situation. Other farmers have adopted water planting as a matter of custom, convenience or both. Water seeding is
sometimes an alternative planting operation when excessive rainfall prevents dry planting methods.

Seedbed preparation is somewhat different when water seeding is used. The seedbed should be left in rougher condition than for dry seeding. This can be accomplished by preparing a seedbed consisting primarily of large clods (approximately baseball-sized). This method may be easier to accomplish with heavy textured soil. Then begin flooding as soon as possible. The rice should then be seeded within three to four days. This will reduce potential weed problems and provide a more favorable oxygen relationship at the soil/water interface. Low oxygen levels are often a problem where flood water is held for a long time before seeding.

A preferable alternative is to prepare a smooth seedbed similar to that for drill seeding then firm with a grooving implement. The result is a seedbed with grooves (1 ½ - 2 inches deep) on 7- to 10-inch centers. In some cases a field cultivator can do an acceptable job. Some producers are constructing tools solely for this purpose. They are based on similar tools used in California and on Louisiana ingenuity.

The rough seedbeds minimize seed drift and facilitate seedling anchorage and rapid seedling development. Seed and seedling drift can often be quite severe, especially in large cuts which are becoming more common as a result of precision leveling. The large clods or shallow grooves provide a niche for the seed to fall into and give some protection from wave action.

Avoid dragging a field in the water before seeding because: (1) Dragging leaves a seedbed in an extremely slick condition, which will often lead to severe seed drift, (2) crusting and curling of the surface after draining is normally more severe where a field has been dragged, (3) when the drag is pulled to an excessive depth, incorporated fertilizers and herbicides are displaced and unevenly distributed and (4) the potential for soil loss during the initial drain is increased by dragging.

Water planting may be accomplished with dry or presprouted seed. Using presprouted seed when water planting offers the advantages of higher seed weight and initiation of germination. Presprouting is accomplished by soaking seed for 24-36 hours and draining for 24-36 hours prior to seeding. Under cool conditions, these periods may need to be extended somewhat. A disadvantage is that seed must be planted shortly after presprouting or deterioration will occur.

Water management of water-seeded rice after seeding may be categorized as prolonged drainage, pinpoint flood or continuous flood.

**Delayed Flood**

When a delayed flood system is used, fields are drained after water seeding for an extended period (usually three to four weeks) before the permanent flood is applied. This system is normally used where red rice is not a problem because it gives no red rice suppression. With this system, fertilization timing and water management after the initial drainage are similar to dry-seeded systems.

**Pinpoint Flood**

The most common water seeding system is the pinpoint flood. After seeding with presprouted seed, the field is drained briefly. This drainage period is only long enough to allow the radicle to penetrate the soil (peg down) and anchor the seedling. Under normal conditions, a three- to five-day drainage period is sufficient. The field is then permanently flooded until the rice nears maturity. (An exception is when midseason drainage is necessary to alleviate straighthead.) Rice plants emerge through the flood. The plant must be above the water surface by at least the fourth leaf stage. Before this stage, the plant normally has sufficient stored food and available oxygen to survive. Atmospheric oxygen and other gases are then necessary for the plant to grow and develop. This system is an excellent means of suppressing red rice
from seeds in the soil. Since the field is maintained in a flooded (or saturated) condition, oxygen necessary for red rice germination is not available.

**Continuous Flood**

A continuous flood system is used on a limited basis in Louisiana. This system is similar to the pinpoint system, except that after seeding, the field is never drained. Of the three water management systems, continuous flood is normally best for red rice suppression, but stand establishment is most difficult. Even the most vigorous variety may have problems becoming established under this system.

Fertilization timing is the same for both the pinpoint and continuous flood systems. Phosphorus, potassium, sulfur and zinc should be preplant incorporated as in the dry-seeded system. Once the flood is applied, the soil should not be allowed to dry.

If the nitrogen requirement is known, all nitrogen should be incorporated preflood-preplant. Otherwise, incorporate 70 percent of the estimated requirement, then apply the additional nitrogen as a topdress at midseason. More information on fertilizer timing in relation to water management is in the Soils, Plant Nutrition and Fertilization section.

### Table 1. Seed per pound and average number of seed per square foot for important rice varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Seed/lb</th>
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<th>100 lb/A</th>
<th>120 lb/A</th>
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**Second Crop Production in Rice**

The climatic conditions of southwest Louisiana, along with the earliness of commonly grown rice varieties, combine to create an opportunity for second crop production. Second crop rice, also known as stubble or ratoon crop rice, is produced from regrowth on the stubble after the first crop has been harvested.

Weather during the fall will normally dictate how successful a farmer can be at producing a second crop. Mild temperatures will speed second crop maturity and can prevent excessive sterility (or blanking) associated with low temperatures at flowering. Remember that average daily high and low temperatures used in
DD-50 based predictions are just as important in the development of second crops. Later than normal first frost dates will help to produce second crops, especially when the first crop was harvested later than August 10. It is recommended that the first crop be harvested at least by the middle of August to assure adequate time for the second crop to develop. In years with an abnormally mild fall and a late first frost, second crops can be produced when the first crop is harvested as late as the first week of September, but this is the exception rather than the rule.

While cooperation from the weather is essential for second crop production, cultural practices can play an extremely critical part in maximizing stubble crop yields. It must be emphasized that cultural practices used in the first crop can have a major impact on second crop production. Excessive rates of nitrogen applied to the first crop can often delay the regrowth of the second crop. Therefore, excessive rates of nitrogen should be avoided even with a variety with high levels of resistance to lodging. Disease pressure in the first crop can have an effect on the second crop. Severe disease pressure in the first crop can actually cause death of tillers and prevent regrowth from these plants. Use of a foliar fungicide in the first crop can be beneficial to the second crop.

Conditions at harvest will influence whether a second crop should be attempted. If it's necessary to harvest under muddy conditions and the field is excessively rutted, second cropping will be difficult and probably should not be attempted. Excessive amounts of red rice in the first crop will also limit yield and reduce quality in the second. It may be beneficial to avoid second crop production and concentrate on encouraging germination of red rice seed followed by destroying the seedlings by fall plowing. This may decrease the red rice problem in succeeding crops.

An application of nitrogen fertilizer will be necessary when striving for high second crop yields. It is normally best to apply the nitrogen to a dry soil surface and establish a shallow flood immediately after harvest. This will facilitate rapid regrowth and efficient use of applied nitrogen.

Consult the annual publication Rice Varieties and Management Tips (Publication 2270) when selecting varieties with the intention of producing ratoon or second crop rice.

**Conservation Tillage Management**

The following information is based in part on specific research results obtained from studies conducted at the Rice Research Station since 1987. Some has been generalized based on observations from these studies and not necessarily scientific measurements. The knowledge base on conservation tillage in rice is still limited, and additional research needs to be conducted. Basic components of these alternative production practices will be summarized emphasizing advantages and disadvantages. This information is adequate for use as a general guideline but may not be applicable to every situation. Three alternative seedbeds have been compared with conventionally prepared seedbeds in both water- and drill-seeded cultural systems. The practices are defined as follows:

**Spring Stale Seedbed**

Land is prepared three to six weeks before planting. Depending on temperature and rainfall, vegetation that establishes before planting is usually small, sparse and easy to control. Most farmers see little advantage to this option when compared with spring seedbed preparation at the normal time. But, this option does offer one important benefit. During dry springs, seedbeds can be worked early and readied for planting. If excessive rainfall occurs before planting, time, money and labor can be saved by controlling preplant vegetation with a burndown herbicide rather than waiting for the seedbed to dry enough to prepare mechanically. This system improves the chance of timely planting.
Fall Stale Seedbed

Seedbeds are completely prepared in the fall. Vegetation that establishes over the winter in this practice is usually uniform in cover, 8 to 10 inches in height, and consists of winter annual grasses, clovers, vetches and other broadleaves. This practice is probably the most popular in the southwest area. Better drying conditions and more favorable weather in the fall allow more opportunity for field preparation.

No-till

Rice is planted directly into previous crop residue or native vegetation. In the southwest area, soybeans would be the typical rotation crop. Cotton and soybeans are options in northeast Louisiana. Preplant vegetation is usually not uniform in size and is usually comprised of much larger, woody winter weeds that pose problems when controlling preplant vegetation. Rice establishment practices used in conservation tillage systems are described below.

Preplant vegetation control -
Roundup and Gramoxone are labeled for burndown in rice. Consult the herbicide label for rate of application and weed control spectrum. Rate depends on type and size of weed, and herbicides should be applied according to label directions. Some rice is no-tilled without termination of preplant vegetation. This is possible if weed growth is minimal and the vegetation is winter annuals that will eventually die out or be killed by flooding. Significant yield reductions have occurred in studies where preplant vegetation was excessive and a herbicide was not used for burndown. Opting not to use a burndown chemical can be risky, and weed identification is extremely important.

Time of application in relation to planting - Best results in most of the research have occurred with a seven- to 10-day preplant application. This is especially true when the residual herbicides are tankmixed with the burndown herbicides. Longer intervals between burndown and planting reduce the effectiveness of residual weed control in the planted rice crop. There are also preplant intervals for Harmony Extra (45-day) and 2,4-D (15-day) applied alone or tankmixed with burndown herbicides. A disadvantage is the extended preplant time intervals, especially with Harmony Extra. All of these herbicides must be applied according to label directions.

Planting practices - Use presprouted seed when water seeding. This will help establish stand more rapidly and minimize germination problems associated with poor floodwater quality, low oxygen, seedling diseases and potential seed midge damage. Seed-to-soil contact is important and is a function of the amount of vegetation and, to some extent, the type of vegetation. When drill seeding, it is important to use planting equipment that places seed at a uniform depth and closes the seed slit to conserve moisture. On some soils, it may not be necessary to use no-till equipment.

Good quality conventional planters perform well on mellow seedbeds. Heavy, no-till equipment is desirable where vegetation is excessive and seedbeds are compacted.

Water management - Reduced stand has been a common problem in water-seeded, no-till rice, especially when pinpoint flooding. Delaying permanent flood establishment for two to three weeks after water seeding and draining will improve stands in some situations. It is important, however, that adequate moisture be provided by rainfall or irrigation in delayed flood systems. Excessive drying of the seedbed during rooting can also cause stand reduction. Delayed flooding is not a desirable management practice when red rice is a problem, and control or suppression of red rice will be significantly reduced when this type of water management is practiced. Red rice control using conservation tillage has been less consistent than conventional water seeding practices.

Stand establishment difficulties encountered when drill seeding have often been associated with lack of moisture. If moisture is inadequate at planting, flush
the field to encourage uniform emergence and stand establishment. Gibberellic acid seed treatment may also enhance emergence of some varieties. In water-seeded systems, seed to soil contact is often poor. As a consequence, frequent flushing in delayed flood systems may be required. In a pinpoint flood system, it may be necessary to drain more than once to encourage rooting.

**Variety selection** - Variety selection in a no-till system is important. Good seedling vigor, tillering ability and yield potential are important characteristics. Under ideal conditions, any commercial variety being grown could be considered. Research supports the fact that no-till and stale seedbeds are not ideal situations, and varieties that possess all of the above characteristics have shown the most consistency. Some semidwarf varieties, such as Lemont, struggle to establish stand in no-till seedbeds, especially when water seeded. Yields have generally been reduced. Varieties that are taller or possess good seedling vigor have performed well.

Cypress is a semidwarf but has excellent seedling vigor and has shown consistency and good yielding ability. Tall varieties, such as Mars and Jackson, are also good candidates. Maybelle has been somewhat inconsistent. Any of these varieties has potential in a no-till system under ideal conditions; however, there is merit to choosing one over another based on the above general criteria.

**Fertilizer management** - Plant nutrients can be surface applied in a no-till system. In stale seedbeds, phosphorus (P) and potassium (K) can be incorporated at the time of land preparation. This is becoming a popular practice with fall prepared seedbeds. Nitrogen management in the spring rice crop is much easier when P and K have already been applied. In areas where scumming may be a problem, P and K should be applied in a no-till system after rice stand has been established but by the fifth leaf stage. These nutrients can be applied into standing floodwater or before permanently flooding.

**When not to no-till** - Excessive vegetation, hard to control weeds, rutted fields, unlevel land and red rice problem fields are all candidates to consider for more conventional planting practices. Heavy vegetation reduces seed-to-soil contact and increases problems establishing adequate stand. Weeds not controlled before planting will cause significant problems with expensive solutions after planting. Rutted fields and unlevel land affect both flooding and draining of rice fields. Water management problems can be detrimental to successful rice production. Control of red rice in no-till fields is still being evaluated. Severely infested fields should be managed by more conventional means.

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**Growth and Development of the Rice Plant**

Richard T. Dunand

**Introduction**

Growth and development of the rice plant involve continuous change. This means important growth events are occurring in the rice plant at all times. Therefore, the overall daily health of the rice plant is important. If the plant is unhealthy during any state of growth, the overall growth, development and grain yield of the plant are limited. It is important to understand the growth and development of the plant.

The changes that occur in the rice plant as it grows and develops occur inside as well as outside and underground as well as above ground. These changes can be grouped into two phases of growth, each of which has several identifiable growth stages based on development of the shoot.

The ability to identify growth stages is important for proper management of the rice crop. As more becomes known about factors affecting rice growth and
development, management practices designed to increase rice production will emerge. These management practices, just as some of those in present use, will be tied to the growth and development of the rice plant. An understanding of the growth of rice is essential for management of a healthy crop and for the proper use of the DD-50 rice management program.

Phases of Growth

The growth and development of rice begin with the germination of the seed and end with the formation of grain. During that period, the growth and development of the rice plant can be divided into two phases: vegetative and reproductive. These two phases deal with the growth and development of different plant parts, and they overlap.

The vegetative phase deals primarily with the growth and development of the plant from germination to the beginning of panicle development inside the main stem. The reproductive phase deals mainly with the growth and development of the plant from the end of the vegetative phase to grain maturity. Both phases are important in the life of the rice plant. They complement each other to produce a plant which can absorb sunlight and convert that energy into food in the form of grain.

The vegetative and reproductive phases of growth are subdivided into groups of growth stages. In the vegetative phase of growth, there are four groups: (1) emergence stages (2) seedling stages (3) tillering stages and (4) internode formation stages. Similarly, the reproductive phase of growth is subdivided into five groups: (1) prebooting stages (2) booting stages (3) heading stages (4) grain filling stages and (5) maturity stages. These growth stages are easily identified.

Growth Stages in the Vegetative Phase

Emergence Stages

There are two emergence stages, germination and emergence. Germination is the first event in the life of a rice plant. When exposed to the proper conditions, the seed swells as moisture is absorbed. Imbibition of water activates the embryo, and the endosperm can serve as a source of nutrients for the growing embryo for about three weeks. In the embryo, two primary structures grow and elongate: the radicle (first root) and coleoptile (protective covering enveloping the first leaf). As the radicle and coleoptile grow, they apply pressure to the inside of the hull. Eventually the hull weakens under the pressure, and the pointed, slender radicle and coleoptile emerge. When the radicle and coleoptile emerge from the hull, the stage of growth of the plant is germination (Fig. 1).

After germination, the radicle and coleoptile continue to grow and develop primarily by elongation (or lengthening) (Fig. 2). The coleoptile elongates until it encounters light. To help the coleoptile to reach light, sometimes a second elongating structure, the mesocotyl, develops (Fig. 3). The mesocotyl originates from the embryo area and is attached to the base of the coleoptile. The mesocotyl and coleoptile can elongate at the same time. They are sometimes difficult to tell apart. Usually the mesocotyl is white, and the coleoptile is off-white, slightly yellowish. Shortly after the coleoptile is exposed to light, usually at the soil surface, it stops elongation. At this time the stage of growth of the plant is emergence.

Seedling Stages

The seedling stages of growth begin when the primary leaf appears shortly after the coleoptile is exposed to light and splits open at the end (Fig. 4). The primary leaf elongates through and above the coleoptile (Fig. 5). It has no typical leaf blade and is usually an inch or less in length. The primary leaf acts as a protective covering for the next developing leaf. As the seedling grows, the next leaf elongates through and past the tip of the primary leaf. Continuing to grow and develop, the leaf differentiates into three distinct parts: the sheath, collar and blade (Fig. 6). A leaf that is differentiated into a sheath, a collar and a blade is complete; thus the first leaf to develop after primary leaf is the first.
complete leaf. This stage of growth is first leaf (Fig. 7).

All subsequent leaves after first leaf are complete leaves. The sheath is normally the bottom-most part of a complete leaf and is an elongated structure which grows upright and surrounds the stem. During the seedling stages, leaf sheaths originate at the base of the stem. In rice, the collar is a small area at the top of a leaf sheath and is the point of origin of the blade. The sheath and collar are the most rigid portions of the leaf. The blade is flexible. The blade angles away from the sheath and is flat with a pronounced, rigid midrib on its underside. The midrib runs the length of the blade and provides support for the blade.

The blade is the part of the leaf where most photosynthesis occurs. It contains more chlorophyll than any other part of the leaf. Chlorophyll is the compound in leaves which absorbs sunlight and converts it to energy for growth. Chlorophyll is green, causing the blade to be the greenest part of the plant. The blade is the first part of a complete leaf to appear as a leaf grows and develops. It is then followed in order by the appearance of the collar at the base of the blade and then the sheath below the collar. During the vegetative phase of growth, only the collar and blade of each complete leaf become fully visible. Only the upper portion of the sheath is visible, since the sheath remains covered in part by sheaths of leaves whose development preceded it.

Since growth and development are continuous, at first leaf the tip of the blade of the second complete leaf usually is already protruding through the top of the sheath of the first complete leaf. The second complete leaf grows and develops in the same manner as the first complete leaf, and when the collar is visible above the collar of the first complete leaf, the stage of growth is second leaf (Fig. 8). Subsequent leaves develop in the same manner, and the stages of growth are classified accordingly as third leaf, etc.

When the second complete leaf matures, the sheath and blade are each longer and wider than their counterparts on the first complete leaf. This trend is noted for each subsequent leaf until about the ninth complete leaf, after which leaf size decreases. Although a rice plant can produce many leaves, as new leaves are produced, older leaves senesce, resulting in a somewhat constant four to five leaves per plant at any given time. The second complete leaf develops on the side of the culm from the first complete leaf. Subsequent leaves develop in this alternate fashion so the third complete leaf is higher on the stem than the second complete leaf and develops on the same side of the stem as the first leaf, producing a pattern referred to as two-ranked and in a single plane. Seedling growth continues in this manner through third to fourth leaf, clearly denoting plant establishment.

The root system begins to develop more fully during the seedling stages. In addition to the radicle, other fibrous roots develop from the seed area and, with the radicle, form the primary root system. The primary root system grows into a shallow, highly branched mass limited in its growth to the immediate environment of the seed. The primary root system is temporary, serving mainly to provide nutrients and moisture to the emerging plant and young seedling. In contrast, the secondary root system originates from the base of the coleoptile. During the seedling stages, the secondary root system is not highly developed and appears primarily as several nonbranched roots spreading in all directions from the base of the coleoptile in a plane roughly parallel to the soil surface. The secondary root system is more permanent. It provides the bulk of the water and nutrient requirements of the plant after the seedling stages.

During the seedling stages, the plant has clearly defined shoot and root parts (Fig. 9). Above the soil surface, the shoot is composed of one or more completely developed leaves at the base of which are the primary leaf and upper portions of the coleoptile. Below the soil surface, the root system is composed of the primary root system originating from the seed and the secondary root system originating from the base of the coleoptile. Plants originating
from seed placed deep below the soil surface will have extensive mesocotyl and coleoptile elongation compared to plants originating from seed placed near the soil surface. Seed placement on the soil surface usually results in no mesocotyl development and little coleoptile elongation. In general, the presence of primary and secondary roots and a shoot which consists of leaf parts from several leaves is the basic structure of the rice plant during the seedling stages of growth.

Tiller Stages

Tillers (stools) first appear as the tips of leaf blades emerging from the tops of sheaths of completely developed leaves on the main shoot. This gives the appearance of a complete leaf that is producing more than one blade. This occurs because tillers originate inside the sheath of a leaf just above the point where the sheath attaches at the base of the plant. If the leaf sheath is removed, the bud of a beginning tiller will appear as a small green triangular growth at the base of the leaf. Tillers which originate on the main shoot in this manner are primary tillers. When the first complete leaf of the first primary tiller is visually fully differentiated (blade, collar and sheath apparent), the stage of growth of the plant is first primary tiller (Fig. 10).

The first primary tiller usually emerges from the sheath of the first complete leaf before fifth leaf. If a second tiller appears, it usually emerges from the sheath of the second complete leaf and so on. Consequently, tillers develop on the main shoot in an alternate fashion like the leaves. When the second primary tiller appears, the stage of growth of the plant is second primary tiller (Fig. 11). The appearance of tillers in this manner usually continues through about fourth or fifth primary tiller. If plant populations are very low (fewer than 10 plants per square foot), tillers may originate from primary tillers much in the same manner as primary tillers originate from the main shoot. Tillers originating from primary tillers are secondary tillers, and, when this occurs, the stage of growth of the plant is secondary tillering.

Tillers grow and develop in much the same manner as the main shoot, but they lag behind the main shoot in their development. This lag is directly related to the time a tiller first appears. It usually results in tillers producing fewer leaves and having less height and slightly later maturities than the main shoot.

During the tillering (stooling) stages, at the base of the main shoot, crown development becomes noticeable. The crown is the region of a plant where a shoot and secondary roots join. Inside a crown, nodes form at the same time as the development of each leaf. The nodes appear as white bands about 1/16 inch thick and running across the crown, usually parallel with the soil surface. With time the nodes become separate and distinct, with spaces (internodes) about 1/4 inch or less in length between them (Fig. 12). Initially the plant tissue between nodes is solid, but with age the tissue disintegrates, leaving a hollow stem between nodes.

In addition to crown development, leaf and root development continue on the main shoot. An additional five to six complete leaves form with as many additional nodes forming above the older nodes in the main shoot crown. On the main shoot, some of the older leaves turn yellow and brown. The changes in color begin at the tip of a leaf blade and gradually move to the base. From this point on, there is continuous aging of older leaves and production of new leaves. The result is that there are never more than four or five functioning leaves on a shoot at one time.

In addition to changes in leaves, the main shoot crown area expands. Some of the older internodes at the base of the crown crowd together and become indiscernible by the unaided eye. Usually no more than seven or eight crown internodes are clearly observable in a dissected crown. Sometimes the uppermost internode in a crown elongates ½ - 1 inch. This can occur if depth of planting, depth of flood, plant population, nitrogen fertility and other factors which tend to promote elongation in rice are excessive. Also during the tiller stages, tiller crowns
develop. Along with growth of the main shoot and tiller shoot crowns, more secondary roots form, arising from the expanding surface of the crowns. These roots grow larger than those which formed during the seedling stages. They are wider and longer at maturity. As the tiller stages end, the rice plant has actively tillered and has some dead and yellowing leaves, a completely developed main stem crown, developing tiller crowns and an actively developing secondary root system.

**Internode Formation Stages**

The formation of internodes (joints) above a crown is the process that produces a stem and determines stem length. Internode formation above a crown begins with the formation of a stem node similar to that of the crown nodes. The stem node forms above the uppermost crown node, and a stem internode begins to form between the two nodes. As the stem internode begins to form, chlorophyll accumulates in the tissue below the stem node. This produces green color in that tissue. If the stem is properly dissected at this time, green color encircling the stem (the green ring) may be apparent. This can be common for all internodes formed above the crown. When the stem node and the uppermost node of the crown of the main shoot are clearly separated, internode elongation has begun and the stage of growth of the plant is first internode or green ring (Fig. 13).

Before the first internode above the crown completes elongation, a second stem node forms above it. A second internode then begins to form below the second stem node and develops in a manner similar to that of the first internode (Fig. 14). This sequence recurs until the last internode elongates completely. As the newly formed nodes on the main stem become clearly separated by internodes, the stages of growth of the plant progress from first internode to second to third, etc. With the formation and elongation of each stem internode, the length of the stem and the height of the plant increase.

Internode elongation occurs in all stems. The main stem is usually the first to form an internode, and it is also the first stem in which internode formation ends. In the tillers, internode formation lags behind the main stem and usually begins in the older tillers first.

During the internode formation stages, each newly formed internode on a stem is longer and slenderer than the preceding one. The first internode formed is the basal most internode. It is the shortest and thinnest internode of a stem. The basal internode is located directly above the crown. Sometimes, if the uppermost crown internode is elongated, it can be confused with the first internode of the main stem.

One difference between these two internodes is the presence of roots. Sometimes, especially late in the development of the plant, the node at the top of the uppermost crown internode will have secondary roots associated with it. The upper node of the first stem internode will usually have no roots. If roots are present, they will be short and fibrous. The last or uppermost internode which forms is the longest and slenderest internode and is directly connected to the base of the panicle. The elongation of the uppermost internodes causes the panicle to be thrust out in the heading stages during the reproductive phase of growth.

Internode length varies, depending on variety and management practices. In general, internode lengths vary from 1 inch (basal internode) to 10 (uppermost internode) inches in semidwarf varieties and from 2 inches to 15 inches in tall varieties. These values, as well as internode elongation in general, can be influenced by planting date, plant population, soil fertility, depth of flood, weed competition, etc.

The number of internodes which forms in the main stem is relatively constant for a variety. Varieties now being grown have five to six internodes form above the crown in the main stem. In tillers, fewer internodes form than in the main stem. The number is highly variable and depends on how much the tiller lags behind the main stem in growth and development.

The time between seeding and internode formation depends primarily on
the maturity of the variety, which is normally controlled by heat unit exposure (see DD-50 Rice Management Program section). It can also be influenced by planting date, plant population, soil fertility, flood depth and weed competition. In general, varieties classified as very early season maturity reach first internode six weeks after emergence. Varieties classified as early season maturity reach first internode seven weeks after emergence, and varieties classified as midseason maturity reach first internode eight weeks after emergence.

The appearance of nodes above the crown marks a change in the role of the node as the point of origin of several plant parts. Before internode formation begins above the crown, all leaves, tillers and secondary roots formed during that time originate from crown nodes. But after internode formation begins above the crown, the nodes serve mainly as the point of origin of all subsequent leaves.

Although possible, significant formation of tillers and roots from nodes above the crown is rare. Since the nodes become separated significantly by internodes, the leaves which originate at these nodes are more separate and distinct than leaves formed before internode formation. The separation of these leaves increases as the length of the internodes increases. Eventually, more complete leaf structure becomes apparent until the last two leaves to form have all or most of all three parts (sheath, collar and blade) completely visible. Since the last leaves formed originate primarily from nodes above the crown, this means that, in varieties now in use, no more than six new complete leaves are produced on the main shoot after stem internode formation begins. The last of these leaves to form is the flag leaf. It is the uppermost leaf on a mature shoot, and the sheath of the flag leaf encloses the panicle during the elongation of the last two internodes.

Root growth approaches a maximum as internode formation above the crown begins. At this time, the secondary root system has developed extensively in all directions below the crown and has become highly branched. Newly formed roots are white; older roots are brown and black. A matted root system forms in addition to the secondary root system. It is composed of fibrous roots, which interweave and form a mat of roots near the soil surface. In general, the root system has developed horizontally to a greater degree than vertically.

Tiller formation usually ceases and tiller senescence (die off) begins during the internode formation stages. More tillers are produced during the tiller stages than will survive to maturity. In those tillers which will not survive, tiller senescence begins as the crown becomes fully differentiated and continues until the last internode forms above the crown. A tiller which does not survive until maturity begins to lag behind in its development. Tiller senescence can be recognized by the smaller size of a tiller in comparison to other tillers on a plant. It appears significantly shorter than other tillers, has fewer complete leaves and fails to have significant internode development above the crown of the tiller. Eventually most leaves on an aging tiller lose coloration while most leaves on other tillers are still green. Finally, the leaves and stems of senescing tillers turn brown and gray and, in most instances, disappear before the plant reaches maturity.

The internode formation stages signal the end of the vegetative stages of growth as markers for determining the stage of growth of the plant. As stem internodes begin to form, the reproductive phase of growth is beginning.

Growth Stages During the Reproductive Phase

Prebooting Stages

The prebooting stages of growth are the only stages during the reproductive phase that occur before leaf formation ceases. During the prebooting stages, the remaining leaves of the plant develop, internode elongation and stem formation continue, and panicle formation begins.

The prebooting stages are identified by the development of the panicle inside the main stem before the appearance of the
sheath (boot) of the flag leaf, the last leaf produced. The prebooting stages follow internode formation and, like internode formation, involve the movement of the growing point inside the main stem away from the crown. Within the growing point is a specialized group of cells which becomes active during the prebooting stages. The specialized group of cells begins actively dividing and differentiates into a small panicle.

When the cells first begin actively dividing in the main stem, the stage of growth of the plant is panicle initiation (PI). Panicle initiation occurs during the fifth week before heading. Although panicle initiation can be positively identified only by microscopic techniques, it is closely associated with the vegetative phase of growth. The growth stages that coincide closely with panicle initiation differ, depending on the maturity of a variety. In very early season varieties, panicle initiation and first internode (green ring) occur at about the same time. In early season varieties, panicle initiation and second internode occur almost simultaneously, and, in midseason varieties, panicle initiation and third internode are closely concurrent.

The specialized group of cells that first begins actively dividing at panicle initiation continues to divide actively. Eventually, a small panicle about 1/8 inch in length and 1/16 inch in diameter forms. At this point, the panicle can be seen inside the stem, looking like a small tuft of fuzz. When this occurs in the main stem, the stage of growth is panicle differentiation (PD) or panicle 2-mm (Fig. 15). The panicle, although small, has already begun to differentiate into distinct parts. Under a microscope, the beginnings of panicle branches and florets are recognizable. The panicle continues to grow during the prebooting stages. When the panicle is 1 inch long, the stage of growth is 1-inch panicle. At this stage, the panicle is a very compact, elongated, slender structure covered with many small knobs. As it grows, the knobby structures differentiate into panicle branches which branch off the main trunk of the panicle (panicle axis) and bear the florets. During the prebooting stages of growth, the panicle branches and florets first become visible at the tip of the panicle. With time, panicle branches and florets appear below the tip.

While these developmental changes are occurring, the panicle continues to elongate. As the panicle grows and develops in this manner and reaches 2 inches, the stage of growth is 2-inch panicle. The identification of the prebooting stages of growth continues in this manner in 1-inch increments until the flag leaf has differentiated on the main stem. At that time the panicle inside the main stem has elongated about 4 inches. The florets at the tip of the panicle are clearly differentiated, while those near the bottom are still in the developmental stages.

**Booting Stages**

The booting stages include a period during which the preflowering growth and development of a panicle and its constituent parts are completed inside the sheath of the flag leaf. The sheath of the flag leaf is the boot, and the booting stages are classified according to its development. Booting is divided into three stages: early, middle and late. Early boot (Fig. 16) occurs when the sheath of the flag leaf first appears above the collar of the penultimate leaf (leaf below the flag leaf) on the main stem and lasts until the sheath of the flag leaf is about 2 inches out of the sheath. Middle boot occurs when the sheath of the flag leaf is 2 to 5 inches out of the sheath, and late boot (Fig. 17) when the sheath of the flag leaf is 5 or more inches out of the sheath of the penultimate leaf.

During the booting stages, the growth and development of the panicle result in a fully elongated panicle with a complete complement of panicle branches bearing mature florets. In the florets, the production of mature pollen begins with the formation of pollen mother cells. This
begins in the uppermost florets on a panicle and progresses down the panicle. The production of mature pollen reaches a maximum during early boot.

Of the panicle parts which become apparent during the booting stages, the panicle branches and florets are the most distinct and contribute greatly to the increase in panicle size. This is apparent in the outward appearance of a stem. As the panicle branches and the florets grow and develop during the booting stages, the sheath of the penultimate leaf and the flag leaf swell. This creates a noticeable bulge in the upper portion of a stem. As the booting stages end, the panicle inside the boot has grown to its final length and is fully differentiated into a main axis with panicle branches bearing fully developed florets. Also leaf development has been completed and only the two internodes directly below the panicle remain to elongate significantly.

**Heading Stages**

The heading stages are associated with the emergence of the panicle through the sheath of the flag leaf on the main stem. (The heading stages are critical for timing of foliar fungicides; see the Disease Management section for more detail.) This process is brought about mainly by the gradual and continuous elongation of the uppermost internodes. As the elongation of the uppermost internodes of the main stem pushes the panicle out of the sheath of the flag leaf and the tip of the panicle becomes visible, the stage is first heading (Fig. 18). The uppermost internodes continue to elongate after first heading, revealing more of the panicle above the sheath of the flag leaf. After the uppermost internode completes elongation, the full length of the panicle and a portion of the uppermost internode are exposed above the collar of the flag leaf. When this has occurred on the main stem, the stage is full heading (Fig. 19).

During the heading stages, pollination begins (Fig. 19). Pollination is the process in which pollen is released, leading to fertilization and grain development. It is identified by the appearance of small, usually white or yellow anthers external to the florets. Sometimes pollination begins shortly after first heading, and sometimes it begins after full heading. Most of the time, the first florets to emerge are the first florets in which pollination occurs. Pollination then continues down the panicle. The panicle in most varieties is green, erect and relatively compact.

**Grain Filling Stages**

During the grain filling stages, the florets on the main stem change to immature grains of rice. The formation of grain results mainly from the accumulation of carbohydrate in the florets. The source of the carbohydrate is the uppermost three to four leaves and the stem. The carbohydrate which accumulates in the florets is stored in the form of starch, and the starchy portion of the grain is the endosperm. The carbohydrate which is translocated from the leaves and stem is white and milky in consistency as it initially accumulates. The first florets which have this accumulation are the first florets pollinated. When this milky accumulation is first noticeable inside florets on the main stem, the stage is milk stage (Fig. 20).

During milk stage, the accumulation of carbohydrate increases floret weight. Since the florets which accumulate carbohydrate first are located near the tip of the panicle, the panicle begins to lean and eventually will turn down. After the first florets which pollinated fill, the carbohydrate begins to solidify. When the texture of the carbohydrate of the first florets pollinated on the main stem is like bread dough or firmer, the stage of growth is dough stage (Fig. 21). As the carbohydrate in these florets continues to solidify during the dough stage, the endosperm becomes firm and has a chalky texture (Fig. 22).

During the grain filling stages, the florets develop and mature unevenly because pollination and subsequently grain filling occur unevenly. In the dough
stage, only the florets on the main stem which pollinated first have an endosperm with the texture of bread dough. At the same time, the florets which pollinated later, including those on the tillers, have endosperms less mature. These are the last florets to accumulate carbohydrate. As more and more florets fill with carbohydrate during dough stage, the translocation of carbohydrate to the panicle starts to decline, and the final phases of grain filling occur.

The panicle changes in color and form as the florets develop and mature. For most varieties of rice, the panicle changes from a uniform light green at milk stage to a mixture of shades of brown and green during dough stage. As the color changes, the shape changes also because of the accumulation of carbohydrate in the florets. The weight of the carbohydrate causes the panicle to bend over and the panicle branches to be less compact around the panicle axis. At the end of the grain filling stages, the panicle on the main culm has a bent and slightly open shape and is various shades of brown and green. The bent and slightly open configuration of the panicle remains unchanged from dough stage to maturity.

### Maturity Stages

The maturity stages occur when carbohydrate is no longer translocated to the panicle. The moisture content of the grain is high after grain filling, and the primary process which occurs in the panicle during the maturity stages is the loss of moisture from the grain. The moisture content of the grain is easily determined. It is used as the basis for the maturity stages of growth. When the physiological processes associated with grain filling cease, and the collective moisture content of the grain on the main stem is 25 percent to 30 percent, the plant has reached physiological maturity.

At this time, the endosperm of all grains on the panicle of a main stem is firm. Most grains are some shade of brown, and the grains in the lower quarter of the panicle are the only ones with a greenish tint. As the maturity stages of growth progress and moisture loss continues, the greenish tint fades and the endosperm of all grains becomes uniformly hard and translucent. When this occurs, and the average moisture content of the grains on the main stem is 15 percent to 18 percent (crop grain moisture, 18 percent to 21 percent), the stage of growth of the plant is harvest maturity (Fig. 23).

### DD-50 Rice Management Program

John K. Saichuk, Steven D. Linscombe and Patrick K. Bollich

The Louisiana DD-50 Rice Management Program helps rice producers manage their crops better. Many cultural practices depend on specific stages in the growth and development of the rice plant. The term DD-50 is derived from degree-day 50, a term referring to a temperature-time value called a heat unit. Because virtually all growth and development processes in rice stop at temperatures at or below 50 degrees F, the term DD-50 is used. No heat units accumulate at temperatures below 50 F, but no negative values are used in the calculations. It is calculated by averaging the maximum daily high and low temperatures in degrees Fahrenheit and subtracting 50.

For example, if the high temperature for a given day is 85 degrees and the low is 60 degrees, then the average temperature (72.5) minus 50 equals 12.5 heat units or DD-50 units for that day. Threshold values of accumulated heat units for various growth stages of rice have been established through research. By adding the heat units from a given stage of growth (emergence is the best), future growth stages can be predicted.

Weather information is obtained from locations around the state and compiled by
Knowing the date of emergence on a field of a particular variety of rice in a particular area of the state enables the program to provide a producer with predictions on when plants in that field will reach certain growth stages. The initial prediction is based on average temperatures and their corresponding heat units in the area over the previous years. Updated predictions are provided as often as needed to compensate for specific conditions in a particular growing season.

The program, provided to Louisiana producers by the LSU Agricultural Center, is coordinated by the county agent in each rice-producing parish. To participate, a producer may fill out a DD-50 card (Fig. 24) for each field or contact a county agent. Accuracy is essential, especially in determining date of emergence. If this information is incorrect, corresponding predictions will be wrong.

The date of emergence depends on the seeding system. If rice is water-seeded (using prolonged drainage, pinpoint flooding or continuous flooding water management), the date of emergence is when the seedlings (shoot) are about 1/2 to 3/4 inches long. With dry-seeded rice (whether drilled or broadcast), the date of emergence is when an average of 10 seedlings are visible (just breaking the soil surface) per square foot. As soon as this date is reached for a particular field, return the completed DD-50 card to the county agent's office.

A printout (Fig. 25) will then be provided showing growth stage predictions and recommended cultural practices based on these growth stages. Again, updated predictions are provided when necessary.

Remember these are just predictions. Fields must still be monitored closely to determine precise stages of development. With the aid of these predictions, critical growth stages can be forecast. The field should be monitored for a particular growth stage about four to five days prior to the predicted date for its occurrence to avoid missing the stage in the event of errors.

Anything which stresses a field of rice will interfere with the accuracy of these predictions. Stresses may include insect pressure, delay of permanent flood, lack of nutrients, disease pressure or many other factors. For maximum yields, avoid these stress factors.

The varieties available with this program will change from year to year as new varieties are released and older varieties are deleted from recommended lists. A personal computer version of the DD-50 program is also available. More information is available from Louisiana Cooperative Extension Service agents.

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**LOUISIANA DD - 50**

**RICE GROWTH STAGE PREDICTION PROGRAM**

**PRODUCER**

**COUNTY AGENT**

**NAME**

**NAME**

**ADDRESS**

**PARISH**

**PHONE**

**FIELD NUMBER**

**VARIETY**

**#OF ACRES**

**DATE OF EMERGENCE**

**SEEDING METHOD: WATER**

**DRY (SOIL)**

PLEASE RETURN TO YOUR COUNTY AGENT

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*Figure 24. D-D50 Rice Management Program Enrollment Card*
### Louisiana DD-50 Rice Management Program

**MID-SOUTH Agricultural Weather Service Center, Stoneville, Miss.**

**National Weather Service and Louisiana Cooperative Extension Service, cooperating**

<table>
<thead>
<tr>
<th>FIELD-NO</th>
<th>FIELD-NAME</th>
<th>ACRES</th>
<th>VARIETY</th>
<th>SEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cypress</td>
<td>125</td>
<td>Cypress</td>
<td>Water</td>
</tr>
<tr>
<td>2</td>
<td>Maybelle</td>
<td>110</td>
<td>Maybelle</td>
<td>Water</td>
</tr>
<tr>
<td>3</td>
<td>Bengal</td>
<td>100</td>
<td>Bengal</td>
<td>Dry</td>
</tr>
<tr>
<td>4</td>
<td>Mars</td>
<td>75</td>
<td>Mars</td>
<td>Water</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Date Description</th>
<th>FLD 1</th>
<th>FLD 2</th>
<th>FLD 3</th>
<th>FLD 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Effective Planting Date</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>2 Date of Emergence</td>
<td>4/20</td>
<td>4/22</td>
<td>4/23</td>
<td>4/25</td>
</tr>
<tr>
<td>3 First Tiller</td>
<td>5/4</td>
<td>5/9</td>
<td>5/12</td>
<td>5/12</td>
</tr>
<tr>
<td>4 Drain for Straighthead</td>
<td>5/19</td>
<td>5/17</td>
<td>5/23</td>
<td>5/23</td>
</tr>
<tr>
<td>5 Begin Checking Internodes</td>
<td>5/29</td>
<td>5/27</td>
<td>6/2</td>
<td>6/2</td>
</tr>
<tr>
<td>6 Check for pH</td>
<td>6/5</td>
<td>6/3</td>
<td>6/11</td>
<td>6/11</td>
</tr>
<tr>
<td>8 Heading</td>
<td>6/30</td>
<td>6/22</td>
<td>7/6</td>
<td>7/6</td>
</tr>
<tr>
<td>9 Harvest</td>
<td>8/4</td>
<td>7/27</td>
<td>8/20</td>
<td>8/20</td>
</tr>
</tbody>
</table>

**NOTE:** These are just predictions. Fields must be closely monitored to assure proper growth stages.

**LSU Ag Center Recommendations - Numbers in the margin correspond to the growth stages listed on the prediction printout.**

- **2** Emergence equals 8-10 seedlings visible per square foot for drill-seeded rice and seedlings around 3/4 inch (average) for water-seeded rice. Pinpoint flood may be started at this time. If Karate is to be used for water weevil control, begin scouting as soon as the field has been flooded or flushed. Treat when adults are present. Continue to scout at least weekly. Two or more applications may be required.

- **3** Majority of plants displaying first tiller. Under normal conditions, nitrogen should be applied and a field permanently flooded by this time (dry-seeded or prolonged seeded drained fields). Research has shown that 70% to 100% of nitrogen should be applied to a dry (if possible) soil surface within 7 days before the permanent flood is applied. If propanil is used, begin flooding within 24 hours of application. In cold, cloudy weather, delay flood 4-5 days to enhance propanil activity.

- **4** Where straighthead is a potential problem, fields should be drained, dried and reflooded before the green ring stage.

- **5** Begin checking for internode elongation (green ring) stage. This is normally the best time for a mid-season nitrogen application (if needed). Begin scouting for foliar diseases. Apply phenoxy herbicides at the first green ring. Do not apply after the second green ring stage. This is the earliest recommended timing for application of any fungicide. If Moncut fungicide is to be used, the first application at 0.7 to 1.0 lb. per acre should be made now with a second application at the same rate to follow in 10 to 14 days.

- **6** Panicle differentiation (panicle 2mm), mid-season nitrogen should be applied at least by this time. If Tilt fungicide is to be used and two (6 ozs. per acre) applications are intended, apply the first at or shortly after this stage. If Quadeis is to be used for sheath blight control ONLY, a single application at 12.3 ozs. per acre should be made 5 to 10 days AFTER panicle differentiation is reached.

- **7** Early boot is when there is a 1- to 2-inch panicle in the boot. First application of Benlate (1 lb. per acre) or Rovral (1 pt. per acre) should be made at this stage. If Quadeis is to be used for blast control, the first 12.3 ozs. per acre application should be made at this time. A second 6 ozs. per acre (or one 10 oz. per acre) Tilt application should be made at this stage, but must be made before heading.

- **8** Heading is when 50% of the stems are showing heads. The second Benlate (1 lb. per acre) or Rovral (1 pt. per acre) or Quadeis (12.3 ozs. per acre for blast control) application should be made. Begin scouting for rice stink bugs. Treatment thresholds are 30 or more per 100 sweeps during the first 14 days after heading and 100 per 100 sweeps from 15 days after heading until hard dough stage is reached.

- **9** Harvest is when a grain sample is around 20% moisture. Normally, fields should be drained two weeks before harvest on silt loams and three weeks before on heavier (clay) soils.

Figure 25. D-D50 printout
Development of rice varieties has been an important tool for improving rice production in Louisiana and in the United States. Release of improved varieties by public breeding programs in Louisiana, Texas, Arkansas, Mississippi and California, in conjunction with advancements in rice production technology, has provided a continuous increase in rice production and quality. Considerable genetic potential exists to improve on current rice varieties, and rice breeding efforts should continue to help improve production in Louisiana.

Rice Varietal Improvement Program

In the early days, Louisiana rice production depended on varietal introductions by individuals. In 1909, the first rice breeding program in the United States was initiated when the Rice Research (Experiment) Station was established at Crowley. The rice breeding activities there were under the direction of USDA scientists from the inception of the program until the Louisiana Agricultural Experiment Station (LAES) assumed responsibility for the program in 1981.
Since its inception, the program has formally released 26 improved rice varieties (Table 2).

To develop a new rice variety, a breeder must first create new genetic combinations. Artificial hybridization is the most common method used to achieve this goal. Old varieties, breeding lines, foreign introductions and mutations compose the pool of genetic materials known as germplasm. From this germplasm, the breeder selects materials with desirable characteristics to use as parents in the hybridization program. The second generation of offspring from hybridization will contain thousands of different combinations of the parents’ characteristics. This is the result of the transfer and recombination of the genes from the parents, and such material is said to show genetic variability. The breeder begins selecting desirable plants in this genetically variable material. The selections are grown and re-selected for many generations until the selected lines begin to breed true. Thousands of lines will be grown and discarded annually. The very best lines which survive the selection process are increased and tested for yield, quality and pest resistance in the advanced testing phase.

The testing program includes on-station, off-station and by cooperating programs. The off-station testing program includes research at several locations in commercial growers’ fields throughout the Louisiana rice production area. In addition to providing performance data in additional environments, each of these off-station locations is used for local field days in cooperation with county agents and specialists with the Louisiana Cooperative Extension Service. These field days provide excellent opportunities for producers to evaluate potential new varieties under conditions similar to their production environment. In addition, advanced testing is conducted at the Northeast Research Station near St. Joseph. The breeding project also conducts cooperative advanced testing with public rice breeders in Arkansas, California, Florida, Mississippi and Texas. Cooperative evaluations of advanced materials are also conducted with breeders and plant pathologists in Argentina, Columbia, Italy and Uruguay.

Typically, eight to 10 years are necessary from the artificial hybridization until seed of a new variety is made available to rice producers. A typical sequence of steps in the development of a new variety is illustrated in Table 3 using the new variety Lafitte as an example.

The breeding project uses a winter nursery facility in Lajas, Puerto Rico, to facilitate varietal development. The nursery typically turns over early generation material to speed the interval from artificial hybridization to early yield testing. The nursery is also often used to increase and purify seed of potential releases. The breeding project, in cooperation with biotechnologists at the Rice Research Station, also uses anther culture to expedite development of homozygous (pure) lines, which can decrease the time from hybridization to initial yield evaluation.

The rice breeding project depends heavily on many cooperating projects for assistance in the development and evaluation of experimental lines. Cooperators include agronomists, entomologists, pathologists, biotechnologists, geneticists, weed scientists, food scientists and physiologists. This cooperation is essential for the success of varietal improvement efforts aimed at numerous characteristics, including but not limited to yield, milling quality, cooking quality, insect resistance, disease resistance, herbicide tolerance, seedling vigor, lodging resistance, fertilizer responsiveness, stress tolerance, earliness and ratooning.

The Rice Breeding and cooperating projects also evaluate potential varietal releases from other breeding projects (both private and public) to determine their adaptability under Louisiana growing conditions. Many rice varieties from out-of-state breeding programs are well adapted to Louisiana and are widely grown.
Rice Varieties: Characteristics and Performance

The two primary grain types grown in Louisiana are long grain and medium grain. Long grains are characterized by a grain length:width ratio of more than 3:1 and typically cook dry and fluffy because of a high to intermediate gelatinization temperature characteristic and a relatively high amylose content. Medium grains typically have a length:width ratio of between 2:1 and 3:1 (usually closer to 3:1) and cook soft and sticky because of a low gelatinization temperature characteristic and a relatively low amylose content. Southwestern Louisiana producers have historically planted from 20 percent to 50 percent of rice acreage in medium grains, and those in northeastern Louisiana grow almost exclusively long-grain varieties. In recent years, the percentage of the state rice acreage planted to medium grains has continually decreased. Interest in special purpose varieties has gained in popularity. These varieties have distinctly different cooking quality attributes, such as aroma, elongation or a unique cooking characteristic that may be favored by many ethnic populations living in the United States as well as other consumers interested in gourmet or premium rice. The major specialty types include soft cooking aromatic Jasmine, flaky cooking elongating and aromatic Basmati, Kokuhoe, waxy, standard long-grain aromatic Della, soft cooking non-aromatic Toro and other less known gourmet types. Most specialty rice marketed in the United States is imported from Thailand, India and Pakistan. Efforts are under way at the Rice Research Station to develop adapted varieties that can be used in the domestic production of imported specialty types. A number of specialty varieties from the Della, Toro and Jasmine groups are under limited production in the southern United States.

Table 4 displays agronomic, yield and quality characteristics of those recommended for Louisiana production in 1998. Data were generated in the commercial variety tests from various locations throughout Louisiana.

The following information is included:
- Days to 50% heading: Average number of days from emergence to 50 percent heading. Most varieties will reach harvest maturity (20 percent grain moisture) within 30 to 40 days after heading under normal conditions.
- Seedling vigor: Visual estimate.
- Plant height: Height at maturity in inches from soil line to extended panicle.
- Lodging: Comparative estimate of resistance to lodging. Most varieties rated as resistant to lodging can lodge, especially under excessive levels of applied nitrogen. Abbreviations are: HR = highly resistant, R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, HS = highly susceptible. Resistance to lodging is generally influenced by both plant height and straw strength.
- Grain yield: Dry weight (converted to 12 percent moisture), lb/A.
- Milling: a) Head = % of whole kernels after milling; b) Total = % of all kernels (whole and broken) after milling.

Recommended Varieties

The following section provides specific information about each recommended variety. The location in parentheses indicates origin of the variety.

**Jodon (Louisiana):** Jodon is a semidwarf, long-grain variety that is a sister line to Cypress. It has displayed good levels of resistance to lodging but may lodge more readily than Lemont-type semidwarfs. This variety has very good seedling vigor and excellent first and second crop yield potential. Milling yields are generally fair to good. Jodon is susceptible to sheath blight and blast and to straighthead. Jodon has amylographic characteristics similar to L-202, which may make it cook slightly softer than other long grains and, thus, be unsuitable for canning processes.

**Jackson (Texas):** Jackson is a sister line to Maybelle (developed from the same cross), but it is seven to 10 days later in maturity and 2 to 3 inches taller than Maybelle. Jackson typically is superior to Maybelle in first crop yield potential. The
variety is susceptible to sheath blight and blast diseases; second crop potential is very good.

**Alan (Arkansas):** Alan is taller and somewhat more susceptible to lodging than the other varieties in this group. First and second crop yield potential is good. Milling yields are generally fair to good. It has excellent seedling vigor. Alan is susceptible to sheath blight and blast.

**Maybelle (Texas):** Maybelle is the earliest maturing variety recommended for Louisiana. Although Maybelle is not a semidwarf, it displays fairly good resistance to lodging. It displays excellent seedling vigor and has good first crop and excellent second crop yield potential. It is susceptible to blast and sheath blight.

**Drew (Arkansas):** Drew is a conventional height, early long-grain variety very similar in appearance to Kaybonnet. It has excellent resistance to predominant blast races. Yield potential of the variety is excellent and milling yields are typically good. It is moderately susceptible to lodging and will stand somewhat better than Kaybonnet.

**Kaybonnet (Arkansas):** This conventional height, early long-grain variety has displayed excellent yield potential and good milling characteristics. The variety has very high levels of resistance to most races of blast common to Louisiana. Kaybonnet is rated as susceptible to sheath blight disease and moderately susceptible to lodging. It has displayed second crop potential.

**Cypress (Louisiana):** Cypress is an early semidwarf long grain that is moderately resistant to lodging. It is somewhat more susceptible to lodging than Lemont, and this is especially a potential problem under excessive rates of nitrogen fertilizer. Cypress has displayed excellent first crop and good second crop yield potential. It has very good seedling vigor. Milling yields are very good and may not be as adversely affected by sub-optimum harvest moistures as other long-grain varieties. This is primarily associated with superior resistance to fissuring. Cypress is susceptible to sheath blight and blast diseases.

**Lemont (Texas):** Lemont is a semidwarf that has displayed very high yield potential, as well as excellent milling characteristics. It has poor seedling vigor, and shallow seeding depth is essential. Because of the short plant height and good straw strength, Lemont is highly resistant to lodging. Lemont is very susceptible to sheath blight and susceptible to blast. It has shown very good ability to tiller (stool) and good second crop potential.

**Rico 1 (Texas):** This variety has excellent yield potential and good milling performance. It has typically yielded higher than other recommended medium-grain varieties in yield trials. It is a tall variety and is susceptible to lodging, especially if nitrogen fertilization rates are too high. Seedling vigor is fair. It ripens very slowly, maturing about one week later than Mars. It is moderately resistant to straighthead, moderately susceptible to sheath blight and susceptible to sheath rot and blast. Rico 1 is characterized by short, plump grains, making it more difficult to dry under certain conditions. It also tends to produce chalky grains, especially under high nitrogen fertilization. As a result, some mills may be reluctant to accept it.

**Bengal (Louisiana):** Bengal is a semidwarf variety that has displayed very good yield potential and excellent milling quality. The milled grains are plumper than other commonly grown medium grains in the South, a characteristic favored for some processing uses. Seedling vigor is good, and Bengal has displayed good second crop yield potential. It is susceptible to blast and straighthead and moderately susceptible to sheath blight. It has displayed susceptibility to panicle blight.

**Lafitte (Louisiana):** Lafitte is a short-statured medium grain that is five to six days earlier in maturity than Bengal. It is 2 to 3 inches taller than Bengal and is more susceptible to lodging. It has displayed good stable yields and consistently had higher head rice yields in testing. Lafitte is resistant to the predominant blast races. Seedling vigor is good, and the variety has displayed good second crop potential in limited testing. It is moderately susceptible
to sheath blight and susceptible to straighthead.

**Other Varieties**

This section provides information on varieties that are not generally recommended but may be grown on limited acreage.

**Dixiebelle (Texas):** The variety has a Newrex-type cooking quality characterized by 2 percent to 3 percent higher amylose content than conventional U.S. long grains. This cooking quality type is favored by the rice canning industry and should be grown on a contract basis. It has fair yield potential and milling quality. It is a semidwarf and has good resistance to lodging. This variety has very poor seedling vigor.

**Gulfmont (Texas):** This semidwarf variety is very similar to Lemont. Gulfmont has normally been somewhat earlier in maturity than Lemont. It has very good second crop potential. Milling yields have been good. Disease reactions are similar to Lemont.

**Jefferson (Texas):** Jefferson is a semidwarf long grain that is about the same maturity as Jodon, Jackson and Alan. About the same height as Lemont, it is highly resistant to lodging. Milling yields are good, but seedling vigor is poor. Jefferson is susceptible to sheath blight and moderately susceptible to blast.

**Katy (Arkansas):** Katy has a high level of resistance to blast disease. It is tall, moderately susceptible to lodging and has good seedling vigor. The variety has shown more resistance to sheath blight than other varieties in this maturity group. It is moderately susceptible to straighthead. Katy has moderate yield potential.

**Lacassine (Louisiana):** Lacassine is less leafy than Lemont or Gulfmont, and the panicle is more prominently displayed. Lacassine, like Lemont and Gulfmont, is highly susceptible to sheath blight and susceptible to blast. It has good first and second crop yield potential. Lacassine also has somewhat poor seedling vigor in a dry-seeded system, and shallow seeding depth is important.

**LaGrue (Arkansas):** LaGrue is a 1993 very early, long grain release. This variety is about 43 inches tall and moderately susceptible to lodging. LaGrue has excellent yield potential. Milling yields are variable, generally averaging less than recommended varieties in this maturity group. LaGrue is susceptible to blast and sheath blight.

**Litton (Mississippi):** Litton is a short-statured long grain that has had only limited testing in Louisiana. It has averaged 1 to 2 inches taller than Cypress but appears to have fairly good resistance to lodging. Litton is two to three days later in maturity than Cypress.

**Mars (Arkansas):** This variety has high yield potential and generally good milling characteristics. Mars is a stiff-strawed variety moderately susceptible to lodging. It is susceptible to blast. Straighthead may also be a problem. Seedling vigor is generally quite good.

**Millie (Arkansas):** Millie is a very early, long-grain variety that is fairly resistant to lodging. It has moderate yield potential and excellent milling characteristics. It is susceptible to blast and moderately susceptible to sheath blight. **Millie has exhibited substantial injury from several widely used rice herbicides.**

**Priscilla (Mississippi):** Priscilla is a semidwarf early long grain variety that has shown good yield potential. It is slightly taller and slightly earlier than Lemont. Milling yields are fair.

**Saturn (Louisiana):** Saturn is an old (released in 1964) medium-grain variety still grown in southwest Louisiana. The variety has good seedling vigor but is tall and extremely susceptible to lodging. Saturn has moderate yield potential and excellent milling characteristics.

**Special Purpose Varieties**

These varieties have special cooking or processing characteristics. They are generally grown on a limited acreage. Because of their unique cooking characteristics, they should not be co-mingled with standard U.S. long-grain varieties.
**Jasmine 85 (Texas):** Jasmine 85 is an aromatic, soft-cooking rice. Because of low amylose content, its grains tend to stick together when cooked. Agronomically, it is a true semidwarf but is somewhat taller than Lemont. It is susceptible to lodging, very resistant to blast, moderately resistant to sheath blight, very susceptible to straighthead and moderately susceptible to panicle blight. Its yielding ability is good to excellent, but milling yields are inferior to current varieties. Because of the noticeable differences in the specialty qualities of Jasmine 85 and imported Jasmine, this variety has not been widely accepted by the traditional consumers of Jasmine rice. Markets should be identified for this cultivar before it is planted.

**Toro-2 (Louisiana):** Toro-2 is a nonaromatic, low amylose (sticky cooking) long-grain special purpose variety. In taste tests, Toro-2 was judged to have acceptable Toro-type cooking and taste characteristics. A true semidwarf variety, it is resistant to the predominant blast races and moderately susceptible to sheath blight. It is very susceptible to straighthead.

**Della (Louisiana):** Della is an aromatic standard long-grain rice favored for its unique popcorn aroma and taste characteristics. It is grown on limited acreage in Louisiana. Della is a midseason variety and displays low yield potential compared to other varieties. Disease susceptibility is often a problem because Della is susceptible to most major rice diseases. It is tall and very susceptible to lodging, even under conditions of low yield potential.

**Dellrose (Louisiana):** Dellrose is a Della-type aromatic long-grain variety recently released by the LAES. Taste panel evaluations indicate similar aroma and flavor ratings between Della and Dellrose. Chemical analysis of rice aroma compound shows the aroma intensity of Dellrose to be higher than Dellmont and lower than Della. Dellrose is a semidwarf variety with high grain yield, high milling yield and high ratoon yield potential. It is susceptible to sheath blight, moderately susceptible to blast and moderately resistant to straighthead.

**Akitakomachi (Japan):** This variety is grown on a very limited acreage for the premium quality market. It is a true short grain with limited yield potential and is very susceptible to lodging. It should not be grown unless a market has been identified.

**Summary**
Variety selection is a critical early step in a successful program. No rice variety is ideal, and relative strengths and weaknesses must be weighed in selecting varieties for each operation. It is generally recommended to plant several varieties to minimize potential problems with adverse weather and disease epidemics. With this in mind, it is beneficial to plant varieties with differential relative strengths and weaknesses, especially relative to disease susceptibility.

For additional updated varietal information, check the Extension Service’s publication 2270, *Rice Varieties and Management Tips*, revised each year.

**Seed Certification**
Once a new variety has been developed, a mechanism is needed to purify, maintain and distribute high quality, genetically pure seed to the rice industry. Seed certification accomplishes this and provides an operating procedure to achieve high quality seed and to guarantee it to the user.

The foundation seed rice program of the Rice Research Station is the first phase in the seed certification process. A small amount of seed of a new variety is supplied by the breeder to the foundation seed project. Single rice panicles are grown in individual rows (one panicle per row) called headrows. This allows the breeder and foundation seed personnel to purify and discard mixtures, off types or outcrosses. Acceptable headrows are combined in bulk to produce breeder seed, which is maintained by the foundation seed project and used to plant the next
### Table 2. Principal rice varieties released from the Rice Research Station in Crowley.

<table>
<thead>
<tr>
<th>Variety</th>
<th>C.I./P.I. No.</th>
<th>Grain type</th>
<th>Year released</th>
<th>Breeders Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colusa</td>
<td>1600</td>
<td>short</td>
<td>1917</td>
<td>Chambliss, Jenkins</td>
</tr>
<tr>
<td>Fortuna</td>
<td>1344</td>
<td>long</td>
<td>1918</td>
<td>Chambliss, Jenkins</td>
</tr>
<tr>
<td>Acadia</td>
<td>1988</td>
<td>short</td>
<td>1918</td>
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</tr>
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<td>Delitus</td>
<td>-</td>
<td>long (A)</td>
<td>1918</td>
<td>Chambliss, Jenkins</td>
</tr>
<tr>
<td>Tokalon</td>
<td>-</td>
<td>long</td>
<td>1918</td>
<td>Chambliss, Jenkins</td>
</tr>
<tr>
<td>Evangeline</td>
<td>1162</td>
<td>long</td>
<td>1918</td>
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</tr>
<tr>
<td>Rexora</td>
<td>1779</td>
<td>long</td>
<td>1928</td>
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</tr>
<tr>
<td>Nira</td>
<td>2702</td>
<td>long</td>
<td>1932</td>
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</tr>
<tr>
<td>Magnolia</td>
<td>8318</td>
<td>medium</td>
<td>1945</td>
<td>Jodon</td>
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<td>Lacrosse</td>
<td>8985</td>
<td>medium</td>
<td>1949</td>
<td>Jodon</td>
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<td>Sunbonnet</td>
<td>8989</td>
<td>long</td>
<td>1953</td>
<td>Jodon</td>
</tr>
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<td>long</td>
<td>1955</td>
<td>Jodon</td>
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<td>8998</td>
<td>medium</td>
<td>1956</td>
<td>Jodon</td>
</tr>
<tr>
<td>Saturn</td>
<td>1415</td>
<td>medium</td>
<td>1964</td>
<td>Jodon</td>
</tr>
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<td>Della</td>
<td>9483</td>
<td>long (A)</td>
<td>1973</td>
<td>Jodon</td>
</tr>
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<td>Vista</td>
<td>9628</td>
<td>medium</td>
<td>1973</td>
<td>Jodon, McIlrath</td>
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<td>LA 110</td>
<td>9962</td>
<td>medium</td>
<td>1979</td>
<td>McIlrath, Jodon</td>
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<td>Leah</td>
<td>9979</td>
<td>long</td>
<td>1982</td>
<td>Trahan, Jodon</td>
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<td>Toro-2</td>
<td>483070</td>
<td>long</td>
<td>1984</td>
<td>McKenzie, Jodon</td>
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<td>Mercury</td>
<td>506428</td>
<td>medium</td>
<td>1987</td>
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<td>Lacassine</td>
<td>548772</td>
<td>long</td>
<td>1991</td>
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<td>Bengal</td>
<td>561735</td>
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<td>1992</td>
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<td>Jodari</td>
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<td>long</td>
<td>1994</td>
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<td>Dellrose</td>
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<td>1995</td>
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<td>Lafitte</td>
<td>593690</td>
<td>medium</td>
<td>1996</td>
<td>Linscombe, Jodari</td>
</tr>
</tbody>
</table>

(A) = Aromatic.

The foundation seed project uses this small amount of breeder seed to plant and produce foundation seed. It is distributed from the Rice Research Station to commercial seed growers who have applied through a county agent for an allotment of foundation seed of a particular variety. Allocation of the foundation seed rice in Louisiana is directed by the Louisiana Seed Rice Growers Association.

The next generation in the seed certification process is registered seed, which is grown by commercial seed rice growers from the foundation seed provided by the Rice Research Station. Registered seed is used to produce the last generation, certified seed, in the certification process. In some instances, certified seed may be produced directly from foundation seed. Certified seed is used by farmers to plant rice crops for milling and cannot be used to produce seed in the seed certification process.

The official seed certifying agency in Louisiana is the Louisiana Department of Agriculture and Forestry. This agency establishes the guides for all aspects of the certification process. All levels of the certification process from breeder seed to
certified seed are monitored, inspected and tested by the Louisiana Department of Agriculture and Forestry. Below are the Rice Seed Certification standards.

**Isolation Requirements**

Fields offered for certification must be clearly separated from other fields by a ditch, levee, roadway, fence or barren

<table>
<thead>
<tr>
<th>Step</th>
<th>Year</th>
<th>ID Number</th>
<th>Stage of Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1988</td>
<td>88CR018</td>
<td>Artificial hybridization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury &amp; x Mercury/Koshihikari</td>
</tr>
<tr>
<td>2</td>
<td>1988</td>
<td>88T1020</td>
<td>F1 - Space plant nursery</td>
</tr>
<tr>
<td>3</td>
<td>1989</td>
<td>89F7034</td>
<td>F2 - Bulk - segregation</td>
</tr>
<tr>
<td>4</td>
<td>1990</td>
<td>9010848</td>
<td>F3 - Headrow - segregation</td>
</tr>
<tr>
<td>5</td>
<td>1991</td>
<td>9120071</td>
<td>F4 - Headrow - segregation</td>
</tr>
<tr>
<td>6</td>
<td>1992</td>
<td>9205777</td>
<td>F5 - Preliminary yield test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>7</td>
<td>1993</td>
<td>9302008</td>
<td>F6 - Uniform Regional Nursery (URN)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Arkansas, Louisiana, Texas, Mississippi, California, Florida)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Advanced yield test (AY)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Five locations in Louisiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>8</td>
<td>1994</td>
<td>9302008</td>
<td>F7 - URN - AY</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial variety test (CV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Five locations in Louisiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>9</td>
<td>1994</td>
<td>9302008 (Puerto Rico)</td>
<td>F8 - Headrow increase</td>
</tr>
<tr>
<td>10</td>
<td>1995</td>
<td>9302008</td>
<td>F9 - URN - AY - CV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Breeder-Foundation seed field</td>
</tr>
<tr>
<td>11</td>
<td>1996</td>
<td>Lafitte</td>
<td>F10 - Release to seed growers</td>
</tr>
</tbody>
</table>

**Table 3. Sequence of events in the development of the rice variety Lafitte.**

<table>
<thead>
<tr>
<th>Step</th>
<th>Year</th>
<th>ID Number</th>
<th>Stage of Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1988</td>
<td>88CR018 (winter cross)</td>
<td>Artificial hybridization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury &amp; x Mercury/Koshihikari</td>
</tr>
<tr>
<td>2</td>
<td>1988</td>
<td>88T1020</td>
<td>F1 - Space plant nursery</td>
</tr>
<tr>
<td>3</td>
<td>1989</td>
<td>89F7034</td>
<td>F2 - Bulk - segregation</td>
</tr>
<tr>
<td>4</td>
<td>1990</td>
<td>9010848</td>
<td>F3 - Headrow - segregation</td>
</tr>
<tr>
<td>5</td>
<td>1991</td>
<td>9120071</td>
<td>F4 - Headrow - segregation</td>
</tr>
<tr>
<td>6</td>
<td>1992</td>
<td>9205777</td>
<td>F5 - Preliminary yield test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>7</td>
<td>1993</td>
<td>9302008</td>
<td>F6 - Uniform Regional Nursery (URN)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Arkansas, Louisiana, Texas, Mississippi, California, Florida)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Advanced yield test (AY)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Five locations in Louisiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>8</td>
<td>1994</td>
<td>9302008</td>
<td>F7 - URN - AY</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial variety test (CV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Five locations in Louisiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Purification</td>
</tr>
<tr>
<td>9</td>
<td>1994</td>
<td>9302008 (Puerto Rico)</td>
<td>F8 - Headrow increase</td>
</tr>
<tr>
<td>10</td>
<td>1995</td>
<td>9302008</td>
<td>F9 - URN - AY - CV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Breeder-Foundation seed field</td>
</tr>
<tr>
<td>11</td>
<td>1996</td>
<td>Lafitte</td>
<td>F10 - Release to seed growers</td>
</tr>
</tbody>
</table>

**Table 5. Isolation Requirements**

<table>
<thead>
<tr>
<th>No. of Feet From Same Variety/ Different Class Planted By</th>
<th>No. of Feet from Other Varieties/ All Classes Planted By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Drill Broadcast Right Angle</td>
<td>Air Parallel Angle</td>
</tr>
<tr>
<td>Ground Drill Broadcast</td>
<td>Right Angle</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

In addition, the following isolation distances will pertain if the adjoining crop is a different class or different variety (Table 5). Any part of the applicant’s field or fields closer than these distances must be harvested before the final inspection or plowed up. Failure to comply with this requirement will disqualify the entire field (Table 6).
### Table 4. Agronomic, yield and milling characteristics of recommended rice varieties, 1998.

<table>
<thead>
<tr>
<th>Maturity and grain type group</th>
<th>Yield (lb/A)</th>
<th>Milling % (head-total)</th>
<th>Seedling vigor</th>
<th>Days to 50% heading</th>
<th>Height (in)</th>
<th>Lodging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Early Long Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jodon</td>
<td>7271</td>
<td>60 - 69</td>
<td>Good</td>
<td>90</td>
<td>38</td>
<td>MR</td>
</tr>
<tr>
<td>Alan</td>
<td>7173</td>
<td>59 - 69</td>
<td>Good</td>
<td>90</td>
<td>42</td>
<td>MS</td>
</tr>
<tr>
<td>Jackson</td>
<td>7047</td>
<td>59 - 70</td>
<td>Good</td>
<td>91</td>
<td>41</td>
<td>MR</td>
</tr>
<tr>
<td>Maybelle</td>
<td>6074</td>
<td>60 - 70</td>
<td>Very good</td>
<td>85</td>
<td>38</td>
<td>MR</td>
</tr>
<tr>
<td>Early Long Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drew</td>
<td>7831</td>
<td>64 - 70</td>
<td>Very good</td>
<td>95</td>
<td>46</td>
<td>S</td>
</tr>
<tr>
<td>Kaybonnet</td>
<td>7729</td>
<td>63 - 70</td>
<td>Very good</td>
<td>95</td>
<td>45</td>
<td>S</td>
</tr>
<tr>
<td>Cypress</td>
<td>7259</td>
<td>66 - 70</td>
<td>Very good</td>
<td>95</td>
<td>40</td>
<td>MR</td>
</tr>
<tr>
<td>Lemont</td>
<td>6750</td>
<td>61 - 70</td>
<td>Fair</td>
<td>97</td>
<td>38</td>
<td>MR</td>
</tr>
<tr>
<td>Medium Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rico 1</td>
<td>8373</td>
<td>60 - 69</td>
<td>Fair</td>
<td>97</td>
<td>44</td>
<td>S</td>
</tr>
<tr>
<td>Bengal</td>
<td>7896</td>
<td>65 - 70</td>
<td>Good</td>
<td>96</td>
<td>38</td>
<td>MR</td>
</tr>
<tr>
<td>Lafitte</td>
<td>7290</td>
<td>67 - 70</td>
<td>Good</td>
<td>89</td>
<td>39</td>
<td>MS</td>
</tr>
<tr>
<td>Special Purpose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dellrose</td>
<td>6789</td>
<td>63 - 71</td>
<td>Fair</td>
<td>94</td>
<td>40</td>
<td>HR</td>
</tr>
<tr>
<td>Toro-2</td>
<td>6020</td>
<td>61 - 71</td>
<td>Fair</td>
<td>97</td>
<td>43</td>
<td>MR</td>
</tr>
<tr>
<td>Della</td>
<td>5642</td>
<td>58 - 69</td>
<td>Fair</td>
<td>96</td>
<td>51</td>
<td>HS</td>
</tr>
</tbody>
</table>

### Table 6. Field Standards

<table>
<thead>
<tr>
<th>Factor</th>
<th>Breeder</th>
<th>Foundation</th>
<th>Registered</th>
<th>Certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land requirement</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
</tr>
<tr>
<td>Other varieties</td>
<td>None</td>
<td>None</td>
<td>10 plants/A</td>
<td>25 plants/A</td>
</tr>
<tr>
<td>Harmful diseases*</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Noxious weeds: Red Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including Black Hull Rice)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spearhead</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>2 plants/A</td>
</tr>
<tr>
<td>Curly Indigo</td>
<td>None</td>
<td>None</td>
<td>4 plants/A</td>
<td>4 plants/A</td>
</tr>
</tbody>
</table>

* Diseases seriously affecting quality of seed and transmissible by planting stock.
Soils, Plant Nutrition and Fertilization
Patrick K. Bollich, John K. Saichuk and Eddie R. Funderburg

Rice requires an adequate supply of plant nutrients throughout the growing season. Four major nutrients and one micronutrient are required by rice in Louisiana. Nitrogen (N) is required on virtually all soils where rice is produced, and it is the single most important nutrient necessary for maximizing yields. Rice also requires relatively large amounts of phosphorus (P) and potassium (K) on certain soils, especially the prairie and flatwoods soils of southwest Louisiana. The alluvial soils (clay and clay loams) in central and northeast Louisiana are typically high in these nutrients and do not respond to P and K applications. Deficiencies in P and K can occur on these soils if landforming operations remove topsoil. Sulfur (S) is adequately supplied by most rice soils unless native fertility is inherently low or topsoil has been removed. Zinc (Zn) is the only micronutrient known to be deficient on some rice soils. As with S, Zn deficiencies occur when native levels are low, where topsoil has been removed and also when cool weather retards root growth during the seedling stage.

Behavior of nutrients in rice is quite different from that of upland crops. Because rice is cultured under flooded conditions, it is important to understand the relationship between nutrient availability and flooded soils to manage these nutrients properly.

Nitrogen

In drained soils, N is present in both the ammonium and nitrate form, and the rice plant is capable of using either. Nitrate N cannot be maintained once a rice soil is flooded, and large losses of N occur through denitrification. Ammonium N is very stable under flooded conditions and remains available to the plant as long as the flood is maintained. Prolonged drainage and aeration of the soil convert the ammonium form of N from both the soil and chemical fertilizers to nitrate. Once the soil is reflooded, any nitrate N is lost rapidly. It is important to flood a rice soil permanently once fertilizer N is applied.

Phosphorus

Phosphorus is present in the soil in organic and inorganic forms. As with all nutrients required by rice, organic forms are not available to the plant. Since organic P is slowly converted to the inorganic form, fertilizer applications of P are very important on soils deficient in this nutrient.

Flooding a rice soil increases the availability of soil P to the plant. Alternate flooding and draining cycles has a significant effect on P availability. When the soil is drained and aerated, P is much less available to the plant. Reflooding will enhance additional P release but a short-term deficiency may occur even where adequate P is present.

Potassium

Soil K is less affected by flooding than N or P. Its availability changes very little with draining and flooding. Potassium is less limiting to growth and grain yield than either N or P, and deficiencies in K have been less frequent than in other nutrients. Potassium nutrition is closely associated with the rice plants’ ability to resist disease, and more emphasis is being placed on the role it plays in overall rice plant nutrition.

Sulfur

Most of the S contained in the soil is in the organic form under both flooded and unflooded conditions. Inorganic S results from the decomposition of organic matter, and the S status of a soil is related to the amount of organic matter present. Some S is also provided by precipitation and irrigation water.

Zinc

Zinc availability is affected by flooding, although the change in soil pH in response to flooding is the reason for the fluctuation in available Zn. It is more available when the soil pH is acidic. Since soil pH moves
toward neutral under flooded conditions, Zn becomes less available in acid soils over time and more available on alkaline soils.

Other Nutrients
Many other nutrients play a role in rice plant nutrition, and flooding has differential effects on their availability. Availability of calcium (Ca) and magnesium (Mg) is not affected to a great extent by flooding. Iron (Fe), manganese (Mn), boron (B), copper (Cu) and molybdenum (Mo) become more soluble under flooded conditions. While these nutrient elements are known to play a role in rice plant nutrition and critical levels in rice plant tissue have been established, documented deficiencies or toxicities have not been recognized in Louisiana.

Rice Plant Nutrition and Fertilization
The most frequently limiting plant nutrients in Louisiana rice in order of importance are N, P, K and Zn. Soil type, native soil fertility, cropping history and agronomic management practices determine when and to what extent deficiencies of these nutrients occur. A soil test is valuable in predicting nutrient deficiencies and appropriate corrective measures. A sound fertility program is essential to maximize yields and use plant nutrient inputs efficiently. Many nutrient deficiencies can be corrected once recognized in the field, but providing required nutrients in sufficient amounts to avoid deficiencies is the best approach to assure maximum rice yields.

Proper fertilizer management is important to increase profitability, minimize inputs, improve nutrient efficiency and mitigate environmental concerns. Efficient fertilizer use requires: 1) proper water management in relation to fertilizer application, 2) selection of the proper fertilizer source, 3) timely application of fertilizers by methods that provide optimum rice growth, grain yield and crop quality and 4) application of the proper amount of fertilizers to ensure optimum grain yields and economic returns. The major plant nutrients required for rice production and their proper source, time of application and rate are discussed in the following sections.

Nitrogen Nutrition, Water Management, Source and Timing
Nitrogen is the most limiting plant nutrient in rice. Maximum yields depend on an adequate supply of N. Suboptimum N applications can decrease yield potential and grain quality and increase the incidence of disease. Deficiency symptoms include yellowing of the older leaves, reduced tillering, browning of leaf tips and shorter plants (Figs. 26-28). Excessive N causes lodging in some varieties, increases the incidence of disease and can cause grain sterility. Because of the relation between N behavior and flooded soils, the efficiency of N in rice is greatly influenced by water management.

Rice is a semiaquatic plant that has been bred and adapted to flooded culture. Flooding a rice soil (1) eliminates moisture deficiency, (2) increases the availability of most nutrients essential to plant nutrition, (3) suppresses weed competition and (4) provides a more favorable and stable microclimate for plant growth and development.

A permanent flood of 2 to 4 inches should be established as soon as possible and maintained throughout the growing season. In dry-seeded rice, apply the permanent flood by the 4th or 5th leaf stage (20 to 35 days after planting). Uniform, level seedbeds allow earlier flooding, which improves nutrient availability and weed control. To avoid stand loss and reduced seedling vigor, dry-seeded rice should not be submerged. In water-seeded rice, a shallow flood is established before planting. Rice seedlings either emerge through a permanent flood (continuous flooding) or the field is briefly drained to encourage seedling anchorage and uniform stand establishment (pinpoint flooding). The field is then reflooded, and the seedlings emerge through the water as in the continuously flooded system.

Avoid draining rice fields after permanently flooding unless extenuating
circumstances exist. Removing the floodwater can result in loss of N, may affect the availability of many other nutrients, encourages additional weed growth and increases the incidence of some diseases. Situations that justify draining include: 1) soils susceptible to straighthead, 2) severe Zn deficiency, 3) application of some herbicides and 4) control of the rice water weevil larvae.

Ammonium sulfate and urea are the most common sources of N in rice. These two sources are equally effective when properly applied. An advantage of urea is its higher N analysis of 46 percent. It is a more economical source since less material is applied per unit of N. Ammonium sulfate contains 21 percent N, and more than twice the amount of material needs to be applied per unit of N. Ammonium sulfate also contains 24 percent S, which makes it an excellent fertilizer source for avoiding or correcting S deficiencies. It may be a slightly more effective N source when N must be applied to saturated soils during the seedling stage. Nitrate forms of N should never be used because of the potential for large losses of N caused by leaching and denitrification.

The ammonium form of N in either urea or ammonium sulfate is very stable in flooded soils and remains available throughout the season. Once N has been applied and the field permanently flooded, soil drying should be avoided or the ammonium N will be converted to nitrate N. This conversion process results in loss of N through denitrification once the field is reflooded.

Nitrogen fertilizer timing depends on the cultural system used. A continuous, available supply of N must be maintained in the soil-plant system to maximize production. The relationship between N timing and water management affects N retention, efficiency and use. The approach to N management in a permanently flooded system (continuous or pinpoint) and a delayed flood system (dry seeded, or water seeded with a delayed flood) is quite different.

In the permanently flooded system, all or most of the total N requirement should be incorporated into a dry soil 2 to 4 inches deep before flooding. Briefly draining the field after seeding to encourage seedling anchorage in a pinpoint flood system will not result in loss of N unless the soil is permitted to dry. It is important to maintain the seedbed in complete saturation to conserve applied N. Additional N should be applied at midseason as needed unless the total requirement was preplant incorporated.

In the delayed flood systems (drill, dry broadcast or water seeded), the permanent flood may not be established until three to four weeks after seeding. It is impractical to apply large amounts of N at seeding in these systems since fertilizer N cannot be stabilized or maintained before permanently flooding. On most soils, it is necessary to provide 15 to 30 pounds of N during the seedling stage to encourage rapid growth and development. Only 10 percent of this amount should be included in the total requirement. All or most of the required N should be applied to a dry soil by the 4th to 5th leaf stage just before permanently flooding. The floodwater solubilizes the N and moves it down into the soil where it is retained for plant use during the growing season. Apply additional N at midseason as needed unless the total amount required was applied pre flooding.

In either a permanent or delayed flood system, an adjustment in N management is necessary when rice fields are drained for straighthead. Straighthead is a physiological disorder (Fig. 29) that occurs on sandy soils, on soils where arsenical herbicides have been previously used and on soils where large amounts of plant residue have been incorporated before planting. Significant yield losses can occur if fields are not drained and completely aerated before panicle initiation. The draining procedure detoxifies arsenical compounds and reduces the buildup of hydrogen sulfide. Since draining usually occurs during midtillering, no more than 50 percent to 60 percent of the required N should be applied preplant or pre flood, with the remainder being applied before reflooding.
Nitrogen requirements vary with variety and soil type. With the exception of N, soil tests can adequately predict the need for rice nutrients. Nitrogen needs cannot be accurately assessed by currently available soil tests. Total N requirements are determined by conducting statewide variety trials. Recommendations are expressed in ranges of application rates that consider soil type, environment and variety. This information is updated each year in the Louisiana Cooperative Extension Publication 2270, “Rice Varieties and Management Tips.”

Research shows that the total N requirement can be applied preplant in a continuously flooded system or preflood in a delayed flood system. Uniform application of N, familiarity with a variety’s requirement, experience with a particular soil and proper water management are critical when using this method. This approach may not be practical commercially when these situations exist: 1) difficulty in applying large amounts of N fertilizer uniformly, 2) water management capabilities are inadequate, 3) unfamiliarity with the variety or land and 4) the seedbed is saturated. Split applications may be more desirable when any of these conditions exist.

Midseason N topdressings are used efficiently by rice provided adequate early season N was applied. A single midseason application is usually sufficient to maximize yield. Multiple applications of midseason N may not be cost effective and could reduce yield if the basal N application was inadequate. Unlike N applications into the flood on seedling rice, N applied into the floodwater at midseason is used efficiently by rice because of its large plant size and extensive root system.

Rice plant growth stages have been used to determine when to apply midseason N. The green ring growth stage (similar to panicle initiation in many varieties) has traditionally been used for timing midseason N. While this growth stage is a good indicator, the overall health of the rice crop before green ring formation must be considered. Tissue analyses and visual assessment are excellent diagnostic tools to determine the N status of rice at midseason. Nitrogen deficiency should be avoided to minimize the potential for grain yield reductions. Midseason N should be applied at the earliest indication of N deficiency, even if the green ring growth stage has not occurred. Late season N applications may also be inefficient and could lead to grain yield reductions. Research indicates that grain yields are not improved when N is applied later than four weeks after green ring. Yields may actually be reduced when N is applied after this time.

Phosphorus Nutrition, Water Management, Source and Timing

Phosphorus deficiency in rice occurs rather infrequently compared to N deficiency. Stunting, reduced tillering, delayed maturity and yield reductions can occur when P is limiting (Fig. 30). Unlike N, water management has little effect on P retention unless soil loss occurs through erosion or removal of floodwater containing high sediment concentrations. Phosphorus availability is influenced by fertilizer placement, soil factors (pH, and Fe and aluminum content) and wetting/drying cycles. Soil flooding increases the availability of P to rice, but alternating wetting and drying cycles can result in fixation of P in the soil and temporary deficiency.

Water soluble sources of P, such as superphosphate and diammonium phosphate, are effective in preventing and correcting mild deficiency. Consider cost effectiveness and the need for other nutrients when choosing the most appropriate source. Factors to consider when determining rate of application include soil type, cropping history, grower experience, and soil and plant tissue analyses. Typical applications of P range from 25 to 50 pounds per acre.

Phosphorus is most available to rice when applied at planting as a band or broadcast and incorporated application. If preplant applications are not possible, apply it before tillering occurs. Since
adequate P is essential for tiller formation, deficiencies at this growth stage can reduce yield potential significantly. Research has shown that P applications to soils deficient in this nutrient are less effective when applied after tillering has begun (four to five weeks after planting).

**Potassium Nutrition, Water Management, Source and Timing**

Potassium deficiencies seldom occur in Louisiana rice soils. Rice plants deficient in K are lighter green, and the leaf edges contain rust-colored spots that give the plant a brown appearance (Fig. 31). Plant height may be reduced, but seldom is yield reduction significant. The role K plays in plant nutrition is probably more important as it relates to disease resistance.

Potassium behavior in the soil is influenced little by water management. Potassium is a very soluble nutrient and is accumulated by the rice plant throughout the growing season. Preplant or early season application in conjunction with N or P is recommended. Potassium chloride and K sulfate are common sources to apply to avoid or correct existing deficiencies. A single application (30 to 60 pounds per acre) is usually sufficient to maintain adequate K in the rice plant. Split applications are not necessary unless the soil is very sandy and leaching occurs. Since most rice soils, even those with a sandy plow layer, contain a clay hardpan that restricts water infiltration, split applications are seldom necessary.

**Sulfur Nutrition, Water Management, Source and Timing**

Sulfur deficiency is difficult to diagnose because it resembles N deficiency. Sulfur is not mobile in the rice plant, and, when deficiency occurs, the entire plant tends to yellow. Inadequate S in the soil and removal of topsoil during land-forming operations contribute to S deficiencies. A soil test can be helpful in identifying soil areas where deficiencies might occur. Ammonium sulfate is an excellent source of S for correcting existing deficiencies. An application of 100 pounds of ammonium sulfate per acre will supply 24 pounds of S, an adequate amount for avoiding or correcting a deficiency in an existing crop. Water management has no effect on S availability or retention in the soil, but may be important as it relates to the application of S-containing N fertilizers.

**Zinc Nutrition, Water Management, Source and Timing**

Zinc deficiency is a common micronutrient deficiency in rice. Early deficiency symptoms include chlorosis and weakened plants that tend to float on the floodwater surface (Fig. 32). Dark brown spots develop on the leaves; when deficiency is severe, stand loss occurs. Zinc deficiency is usually referred to as bronzing because of the rusty appearance that develops. Calcareous soils with an alkaline pH, inadequate Zn levels in the soil, removal of topsoil during landforming, excessive lime applications, deep water during seedling growth and cool weather that retards root growth during the seedling growth stage may all contribute to Zn deficiency. Deficiencies most often occur in early planted, water-seeded rice because of low temperatures and poor root growth. Since stand loss can occur when deficiency is severe, it is important to recognize deficiency symptoms early.

A soil test can identify soils prone to Zn deficiency. Inorganic Zn salts, such as Zn sulfate or Zn chloride, may be applied with other required fertilizer nutrients at planting. In dry-seeded rice, incorporate Zn to a shallow depth. In water-seeded rice, Zn is more available when applied to the soil surface in close proximity to the developing root system.

Plant uptake of Zn is affected by temperature and adequate root growth. Preplant applications of Zn do not guarantee that deficiencies will not occur. If Zn deficiencies begin to develop in seedling rice, corrective applications need to be considered. Favorable growing conditions that include high temperatures and sunlight may help correct mild Zn deficiencies. Removal of the floodwater for a brief period will also alleviate mild
deficiency. When deficiency is severe and the potential for stand loss exists, apply Zn as a foliar application. Chelated and ligninsulfonate complex sources are most effective for correcting deficiency.

Either inorganic salts or chelated forms of Zn may be applied preplant. Inorganic forms should be applied at a rate of 8 to 10 pounds of actual Zn per acre. Apply chelated sources at a rate to deliver 1 to 2 pounds of actual Zn. Foliar sprays should be applied in a chelated form at a rate of one-half to 1 pound of actual Zn per acre. Use the higher rate when deficiency is severe.

Fall Fertilizer Applications
Fertilizer nutrients are most efficiently used by rice when applied immediately before seeding and no later than permanent flood establishment. There are situations when fall application of some nutrients may be a suitable alternative. These include: 1) no-till and stale seedbed rice production when soil incorporation at planting is not possible, 2) rice fields worked in the water prior to planting when there is concern of fertilizer movement and nonuniform redistribution after mudding in and 3) where scumming is a problem when fertilizer is applied into the floodwater on seedling rice. Advantages to fall application of P and K include more flexibility in early season N applications and more opportunity to apply these nutrients by ground application. Disadvantages include poor retention of K on sandy soils because of leaching and fixation of P on low pH soils containing high levels of iron and aluminum. Never apply nitrogen and Zn in the fall.

Weed Management
David Jordan and Dearl E. Sanders

Introduction
Weeds compete with rice for water, nutrients, space and light. Direct losses from weed competition are measurable and can be great. Indirect losses such as increased costs of harvesting and drying, reduced quality and dockage at the mill, and reduced harvest efficiency are not readily measured but can reduce profits.

Numerous grasses, broadleaf weeds and sedges can be economically damaging in rice. Weeds can grow and thrive in aquatic or semiaquatic environments common to rice culture. Barnyardgrass (Figs. 33, 34), broadleaf signalgrass (Fig. 35), red rice (Fig. 36), hemp sesbania (Figs. 37, 38), alligatorweed (Fig. 39), dayflower (Fig. 40), ducksalad (Fig. 41), redstem, jointvetch (Fig. 42) and annual and perennial sedges (Figs. 43-45) are among the most common weeds. Although weeds vary in their ability to compete with rice, most fields contain a complex of weeds which will reduce yield and quality if an appropriate weed management strategy is not implemented.

Rice weed control is best accomplished by using a combination of cultural, mechanical and chemical control practices. Relying on a single control practice seldom provides adequate weed control. A thorough knowledge of the weeds present in each field is critical in developing appropriate management strategies.

Cultural Control
Purchasing seed rice that is weed free is an important first step in preventing weeds from becoming established, especially in the case of red rice. Red rice has been spread largely by planting commercial seed that is contaminated with red rice. Red rice is a wild rice that is similar to commercial rice. Besides reducing commercial rice yields, the red pericarp (Fig. 46) of this noxious rice can contaminate milled rice. Additional milling can help remove the red discoloration but often will lead to reduced head rice yields through breakage of kernels. Cooking attributes of rice can be altered if significant amounts of red rice are present.
in milled rice. No herbicides are available that selectively control emerged red rice in a commercial rice field, so preventing red rice from becoming established is critical.

Presence of red rice dictates production systems and weed control options and decreases flexibility. Rotating rice with other crops can reduce future weed problems. Successful rotations with soybeans primarily and to a lesser extent with corn, sorghum, soybeans or cotton have reduced levels of red rice in later rice crops.

Proper water management is a key component in controlling weeds. Several different water management schemes have evolved in Louisiana. Permanent flood and pinpoint flood cultures were developed in water-seeded rice to reduce weed problems. These practices attempt to maintain a saturated seedbed. Saturated seedbeds prevent weed seeds from germinating because of the absence of oxygen.

Establishing a good stand of rice and providing an environment that promotes rapid growth also help to minimize weed interference. Optimum plant populations and adequate fertility, insect, disease and water management contribute to the ability of rice plants to compete with weeds.

Management of weeds is critical for optimum rice production in both water- and dry-seeded systems. Although herbicide options and management strategies differ under these systems, managing herbicides and water in a timely manner is critical.

Water-seeded rice

Most of the rice grown in Louisiana, especially in the southern part of the state, is water seeded to control red rice (see red rice section). Weed populations shift from terrestrial weeds in dry-seeded systems to aquatic weeds in water-seeded systems. Red stem, ducksalad, alligatorweed and rushes are prevalent in water-seeded systems. Grasses such as barnyardgrass and broadleaf signalgrass as well as some warm-season perennial grasses (such as water bermuda) (Fig. 47) in some areas can be a problem also.

In water-seeded systems, Bolero or Ordram are applied before seeding to suppress aquatic weeds and grasses. After seedling establishment, propanil, Arrosolo and Facet are used to control grasses and broadleaf weeds. These herbicides are often supplemented with Basagran to control ducksalad and red stem. The field is generally drained briefly to expose weeds to herbicides. When doing so, it is important that the soil remain wet in fields where red rice is present. Allowing the soil to dry can result in reinestation by red rice.

Granular Ordram also controls grasses and can be applied directly in the floodwater. Londax has become a standard for use in water-seeded rice to control ducksalad and other difficult-to-control aquatic weeds. Applying Londax at the appropriate timing is critical to control. Londax is applied into the floodwater before aquatic weeds have surfaced, and a stationary flood must be maintained for seven days for acceptable control. Some dealers offer fertilizer materials impregnated with Londax, an effective application that reduces cost.

Several herbicides are available for post-flood weed control in both water- and dry-seeded systems. Facet, Blazer, Basagran, Grandstand, Londax and 2,4-D are registered for use. Selection of these herbicides should be based on the spectrum of weeds and restrictions on use. For example, 2,4-D use is prohibited where rice is grown in close proximity to cotton and other 2,4-D-sensitive crops. Although registered for use, apply Whip 360 only in salvage situations when other herbicides have failed to control grass weeds. Excessive rice injury can occur. Precautions on variety selection and cultural practices that may contribute to injury should be considered before use.

Dry-seeded production

In this system, four to six weeks may elapse between planting and permanent flood establishment, and controlling weeds during this period is critical for maximizing yields. During this period barnyardgrass, broadleaf signalgrass, sprangletop (Fig.
48), morningglories (Fig. 49), texasweed (Figs. 50, 51), eclipta (Fig. 52), jointvetch, smartweeds (Fig. 53) and hemp sesbania can become established. Timely herbicide applications made to small weeds, flushes to activate herbicides, and establishment and maintenance of a permanent flood as soon as possible will improve weed control.

The residual herbicides Prowl, Facet and Bolero can provide residual weed control up to permanent flood establishment, and these herbicides have proved valuable in dry-seeded production. They are especially beneficial when delays in permanent flood establishment are anticipated or on clay soils where cracking of soil promotes numerous weed flushes as well as difficulty in establishing and maintaining a permanent flood. Although these herbicides do not always provide complete control, when applied in a program with propanil or Arrosolo, these herbicides generally provide adequate control up to permanent flood establishment. These herbicides, and in particular Facet, are more effective when fields are flushed or when adequate rainfall occurs for activation.

Propanil, Arrosolo and Facet are used routinely to control emerged weeds before flood establishment. Propanil is a contact herbicide with no residual activity. Arrosolo contains both propanil and molinate, and it provides contact and limited residual weed control. Facet controls emerged weeds, but, unlike propanil and Arrosolo, root absorption of Facet is important. Flushing or adequate rainfall shortly after application of Facet is needed for activation regardless of whether or not weeds have emerged. Combinations of contact herbicides such as propanil and Arrosolo with the residual herbicides like Facet, Bolero or Prowl are generally needed for grass control, and these broadleaf herbicides are used to broaden the spectrum of control. Grandstand controls morningglories, jointvetch and alligatorweed. Londax and Basagran are used to control sedges and certain broadleaf and aquatic weeds.

Herbicide programs should be developed based on the complex of weeds present in each field. Scouting fields and accurately identifying weeds are critical in formulating herbicide programs. For example, Facet provides excellent control of barnyardgrass but does not control sprangletop. Relying on Facet alone for weed control will result in sprangletop escapes which can compete with rice. An additional herbicide application will be needed to control sprangletop, and the delay in application caused by misidentification can make sprangletop more difficult to control. Annual sedges can often be controlled with propanil or Arrosolo, but these herbicides seldom control yellow nutsedge adequately when applied alone; Basagran or Londax is generally needed.

In dry-seeded systems, pulling levees as soon as possible after planting can improve weed control by allowing fields to be flushed and flooded in a timely manner. Without levees, using water as a management tool is impossible. On coarse-textured, silt loam soils, pulling levees is much easier than on finer-textured, clay soils. Although rainfall shortly after planting is beneficial for establishing a rice stand and reducing the need for flushing, excessive rainfall can prevent levee construction on clay soils. Pulling levees as soon as the rice is planted when the soil is still relatively dry can prevent or reduce problems in preparing levees on wet soils.

**Adjuvants and Spray Additives**

Postemergence herbicide performance can be greatly influenced by adjuvants. Grandstand, Londax, Basagran, Facet and the dry formulations of propanil must be applied with a suitable adjuvant to control emerged weeds. Gramoxone Extra and Harmony Extra applied as burndown treatments require adjuvants. In contrast to
these herbicides, adjuvants will not improve control with emulsifiable propanil, Arrosolo or Whip 360. Bolero, Facet (preemergence or delayed preemergence), Prowl or Ordram applied to the soil before weed emergence does not require adjuvants. When a liquid propanil formulation or Arrosolo is applied with Grandstand, Londax, Facet or Basagran, additives are not needed. When Facet or dry formulations of propanil are mixed with these predominantly broadleaf herbicides, however, an adjuvant should be included.

Adjuvant cost is much lower than the cost of a herbicide application, especially when several herbicides are applied as a mixture. Not using an adjuvant or selecting a poor quality adjuvant can reduce weed control greatly. Consult the herbicide label for recommendations of the type of adjuvant (crop oil concentrate, nonionic surfactant, etc.) and the proper rate to use.

**Reduced-tillage and stale seedbed systems**

Producing rice in stale seedbed, reduced-tillage or no-till systems requires use of burndown herbicides applied before seeding in water-seeded systems and before rice emergence in dry-seeded systems. Timing of application will depend on the spectrum and size of weeds, anticipated planting date and label restrictions. The key is to have a weed-free seedbed when the rice emerges (dry-seeded rice) or when the flood is established in water-seeded systems. A problem associated with no-till, water-seeded rice is poor water quality and low oxygen resulting from decaying plant residue. Timely vegetation management can minimize this situation. Roundup Ultra, Gramoxone Extra, 2,4-D and Harmony Extra are registered for use in rice. Applying combinations of Roundup Ultra with 2,4-D or Harmony Extra increases control of some broadleaf weed species and may broaden the spectrum of control. Each of these has strengths and weaknesses, and herbicide programs should be tailored to control the existing weed spectrum. Gramoxone Extra has the advantage of rapid kill of weeds and requires only a two-day period before the flood can be established for seeding in water-seeded systems. This is an advantage in controlling red rice.

These herbicides also have restrictions on preplant intervals which can potentially limit utility. For example, Harmony Extra cannot be applied within 45 days of planting. Additionally, various formulations of 2,4-D are available, and labels vary on rates and preplant intervals. Applying Roundup and Gramoxone Extra with residual herbicides such as Bolero, Prowl and Facet can improve early-season weed control. Bolero can be applied in dry- and water-seeded systems, and Prowl can be applied only as a delayed preemergence application in dry-seeded systems. Facet can be applied preemergence or delayed preemergence in dry-seeded systems. It is critical to establish a weed-free seedbed for the emerging rice in dry- and water-seeded systems. When weeds are not controlled and rice has emerged, control can be difficult with in-season herbicides for most winter annual and perennial weeds. Also, summer annual weeds that are not controlled before rice emergence will be older, larger and often harder to control with propanil or other rice herbicides.

**Weed Resistance**

Some weeds have developed resistance to herbicides. In situations where weeds are not controlled with labeled rates of herbicides applied under environmental conditions which are favorable for herbicide activity, these weeds may be resistant. Repeated use of propanil has resulted in development of biotypes throughout the Mid-South that can no longer be controlled with propanil. Aquatic weeds in California have developed resistance to Londax. Rotating herbicides and crops, and applying tank mixtures consisting of herbicides with different mechanisms of action, may prevent or delay development of resistance in Louisiana. For example, mixtures of
propanil with Facet, Bolero or Prowl include at least two different mechanisms of action and reduce selection pressure. Rotating rice with soybeans or other crops will allow use of soil-applied herbicides or postemergence grass herbicides which can control barnyardgrass and red rice. These herbicides have mechanisms of action that differ from most rice herbicides.

If weed resistance is suspected, contact your county agent so an alternative herbicide program can be developed and resistance can be monitored. In addition to developing potential weed resistance, repeated use of a single herbicide will exploit the weakness of the herbicide and may shift the weed spectrum to weeds that may be more difficult to control. This has been especially true in continued use of Facet only, which has resulted in a shift from barnyardgrass as the primary grass weed to sprangletop.

Red Rice Management

Because red rice and commercial rice are so closely related genetically, herbicides that control red rice will generally kill commercial rice. Water management alone can often effectively suppress red rice and reduce competition. Presence of red rice mandates that rice be produced in a water-seeded system, preferably the pinpoint production system. Uniform, level seedbeds are critical for success. In this system, a flood is established with dry or presoaked rice seeded directly into the flood. Presoaked seed is preferred because it gives the commercial rice an additional advantage over the red rice. Before flying on the rice seed, the field is tilled to muddy the water and kill germinated red rice that would otherwise emerge through clear water. This type of tillage can be difficult on clay soils. Depending on environmental conditions, the flood is removed and rice seedlings are allowed to peg into the soil. An advantage of presoaked seed is that the flood can be removed sooner than with dry rice. This can reduce the time seeds are exposed to wind and drift within bays and can help lead to a more uniform stand. After rice seedlings have anchored, the flood is brought up slowly until the permanent flood is established. Maintenance of flooded soil conditions reduces emergence of red rice and other weeds. Water management in this system is critical, and breakdowns in control usually result from inadequate flood maintenance.

Although Bolero and Ordram suppress red rice, they do not provide complete control. Using these herbicides in combination with water management, however, can minimize interference from red rice. Rotating rice with soybeans or other crops and controlling red rice with effective herbicides are important in managing red rice.

Summary. Numerous herbicides and tank mixtures of herbicides are available for use in rice, and, with the exception of red rice, adequate weed control can be obtained when these herbicides are applied in a timely manner coupled with appropriate water management. Early-season weed interference can be very detrimental and can reduce yields even though control practices are implemented later. Failure to apply herbicides in a timely manner may result in poor weed control and the need for repeat applications. These situations allow more early-season weed competition and generally less effective control.

Before using a herbicide, follow all directions and precautions. In addition to being illegal, failure to follow the label can result in poor weed control, excessive rice injury and environmental and safety hazards.

Herbicide Options

Herbicides in these tables have been evaluated by Louisiana Agricultural Experiment Station researchers under a variety of environmental conditions. Recommendations and ratings reflect the average expected performance used in accordance with label specifications. The efficacy of these herbicides on important rice weed species is presented in Tables 7 and 8. Specific recommendations for herbicide use are in Table 9.
Table 7. Weed response to preplant and preemergence burndown herbicides. 1. Poor (P) = less than 49%, Fair (F) = 50-69%, Good (G) = 70-89%, Excellent (E) = 90-100%, “-” = not rated.

<table>
<thead>
<tr>
<th>Gramoxone Extra</th>
<th>Annual Bluegrass</th>
<th>Annual Ryegrass</th>
<th>Carolina Foxtail</th>
<th>Little Balsam</th>
<th>Buttercup</th>
<th>Carolina Geranium</th>
<th>Chickweed</th>
<th>Curly Dock</th>
<th>Coleleaf Evening Primrose</th>
<th>Henbit</th>
<th>Marestail</th>
<th>Speedwells</th>
<th>Shepherdspurse</th>
<th>Shawna/bittercress</th>
<th>Smartweed</th>
</tr>
</thead>
</table>
| 2,4-D E P P P P E G P G E P F G E G F F | 1. Burndown herbicides control only emerged weeds. A residual herbicide can be tank-mixed to extend the weed control. Follow label directions.
### Table 8. Weed response to in-season herbicides and herbicide combinations. Poor (P) = less than 49%, Fair (F) = 50-69%, Good (G) = 70-89%, Excellent (E) = 90-100%, “-” = not rated.

| Palmleaf Morningglory | Eldlpa | Barnyardgrass | Red Rice | Spangletop | Signalgrass | Sedges | Alligatorweed | Ducksalad | Redshelm | Hemp Sesbania | Waterhyssop | Jointvetch | Dayflower | Texasweed |
|-----------------------|-------|---------------|--------|----------|------------|-------|--------------|---------|---------|-------------|------------|-----------|----------|
| PREPLANT BURNDOWN     |       |               |        |          |            |       |              |         |         |              |            |           |          |           |
| Roundup Ultra         | F     | G             | E      | F-G      | E          | E     | F            | F       | G       | E           | F          | E         | E        | E          |
| 2,4-D<sup>1</sup>     | E     | E             | P      | P        | P          | P     | P-F          | G-E     | E       | E           | E          | E         | E        | E          |
| Gramoxone Extra       | F     | G             | G-E    | G        | G          | F-G   | P            | G       | E       | -           | E          | G         | F-G      |            |

| PREEMERGENCE          |       |               |        |          |            |       |              |         |         |              |            |           |          |           |
| Bolero (PPS)<sup>2</sup> | P    | G             | G     | G<sup>3</sup> | G          | F    | E            | P       | E       | G           | F          | F         | E        | P          |
| Ordram (PPS)<sup>2</sup> | P    | P             | G     | G        | P          | P    | G            | P       | P       | P           | P          | P         | P        | P          |
| Bolero (Delayed)<sup>3</sup> | P    | P             | G     | G        | F          | P    | E            | E       | E       | P           | E          | E         | P        | P          |
| Facet                 | E     | -             | E     | P        | P          | P    | G            | P       | G       | -           | -          | -         | P        |            |
| Prowl (Delayed)<sup>4</sup> | P    | P             | G     | G        | P          | P    | P            | P       | P       | P           | P          | P         | P        | P          |

| POSTEMERGENCE         |       |               |        |          |            |       |              |         |         |              |            |           |          |           |
| Arrosolo              | G     | G             | E      | P        | E<sup>5</sup> | E  | E<sup>6</sup> | P    | G<sup>5</sup> | G<sup>5</sup> | E         | -  | G<sup>5</sup> | G<sup>5</sup> | E          |
| Propanil              | F     | G             | E      | P        | E<sup>5</sup> | E  | E<sup>6</sup> | P    | G<sup>5</sup> | G<sup>5</sup> | E         | -  | G<sup>5</sup> | G<sup>5</sup> | G          |
| Ordram<sup>2</sup>    | P     | P             | G     | P        | P          | P    | P            | P       | P       | P           | P          | P         | P        | P          |
| Grandstand            | E     | G-E           | P      | P        | P          | F    | G-E          | G       | G       | P           | F          | E         | G        | G          |
| 2,4-D Amine           | E     | E             | P      | P        | P          | P    | P-P          | G<sup>8</sup> | G    | E          | E          | E         | G        | E          |
| Blazer                | F     | F             | F      | F        | F          | P    | P            | P       | P       | -           | -          | E         | -        | F          |
| Basagran              | F     | G             | P      | P        | P          | P    | E            | P       | F    | E          | F          | G         | P        | E          |
| Prowl + Propanil      | F-G   | G             | E      | P        | E<sup>5</sup> | E  | E<sup>5</sup> | P    | G<sup>5</sup> | G<sup>5</sup> | E         | -  | G<sup>5</sup> | G<sup>5</sup> | G          |
| Facet<sup>6</sup>     | E     | G             | E      | P        | P          | E    | P            | F       | P    | G          | -           | -         | F        |           |
| Bolero<sup>2</sup> + Propanil | G    | G             | E      | P        | E          | E    | E            | P    | G<sup>5</sup> | G<sup>5</sup> | E         | -  | G<sup>5</sup> | G<sup>5</sup> | G          |
| Londax                | G     | G             | P      | P        | P          | P    | E            | F       | E    | E          | P          | E         | G        | G          |
| Facet + Propanil      | E     | G             | E      | P        | E<sup>5</sup> | E  | E<sup>6</sup> | F    | G<sup>5</sup> | E<sup>5</sup> | E         | -  | G<sup>5</sup> | G<sup>5</sup> | E          |
| Londax + Propanil     | E     | E             | E      | P        | E<sup>5</sup> | E  | E            | F    | E    | E          | E          | E         | G        | E          |
| Granstand + Propanil  | E     | E             | E      | P        | E<sup>5</sup> | E  | E            | G-E    | G    | E          | E          | E         | G        | G          |
| Granstand + Arrosolo  | E     | E             | E      | P        | E          | E    | E            | E    | E    | E          | E          | E         | G        | E          |
|Granstand + Facet      | E     | E             | E      | P        | E          | F    | E            | P    | E    | G          | F          | E         | G        | G          |

1. 2,4-D labels differ in the length of time required between applications and planting.
2. See label for variety susceptibility.
3. With proper water management.
4. Drill-seeded rice after susceptibility.
5. Controlled only when small (less than 2 leaves).
6. A few sedges are controlled.
<table>
<thead>
<tr>
<th>Herbicide and rate in lbs. Active ingredient per acre</th>
<th>Rate of formulated material per acre</th>
<th>Weeds controlled</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burndown Options</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>glyphosate, 0.5 - 1.5 lb/A</td>
<td>Roundup Ultra, 1 - 4 pts/A</td>
<td>Emerged weeds</td>
<td>Apply at least 7 days before flood establishment in water-seeded systems. Prior to rice emergence in dry-seeded system. Requires 7 to 21 days to kill most weeds. Applying with either 2,4-D or Harmony Extra may broaden the spectrum of control. See label for preplant intervals. Apply when weeds are actively growing.</td>
</tr>
<tr>
<td>paraquat, 0.5 - 1.5 lbs/A</td>
<td>Gramoxone Extra, 2 - 3 pts/A</td>
<td>Emerged annual weeds. May defoliate perennial weeds but will not kill them.</td>
<td>Apply at least 2 days before flood establishment in water-seeded systems. Prior to rice emergence in dry-seeded systems. Add surfactant at 0.25 - 0.5% on a volume basis.</td>
</tr>
<tr>
<td>2,4-D, 0.5 - 1.0 lb/A</td>
<td>Various formulations, 1 - 2 pts/A of 4 lb/gal material</td>
<td>Emerged broadleaf weeds</td>
<td>Apply at least 2 weeks before planting or flood establishment depending upon the formulation. Add surfactant at 0.25 - 0.5% on a volume basis.</td>
</tr>
<tr>
<td>thifensulfuron + tribenuron, 0.015 - 0.023 lb/A</td>
<td>Harmony Extra, 0.33 - 0.5 oz/A</td>
<td>Emerged broadleaf weeds</td>
<td>Apply at least 45 days before planting. Add surfactant at 0.25%.</td>
</tr>
<tr>
<td>glyphosate + thifensulfuron + tribenuron, 0.5 - 1.5 + 0.15 - 0.023 lb/A</td>
<td>Roundup Ultra + Harmony Extra 1 - 4 pts/A + 0.33 - 0.5 oz/A</td>
<td>Improved control of curly dock, cutleaf evening primrose and smartweed.</td>
<td>Apply at least 45 days before planting. Add surfactant at 0.25% on a volume basis.</td>
</tr>
</tbody>
</table>
### DELAYED PREEMERGENCE (DRY SEEDED)

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Rate</th>
<th>Adjuvant</th>
<th>Application Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>thiobencarb</td>
<td>4 lbs/A</td>
<td>Bolero 8E</td>
<td>Sprangletop, barnyardgrass and aquatic weeds. Will not control emerged weeds. Does not control broadleaf signalgrass. Apply 1 - 5 days before rice emerges. Adequate rainfall or flushing is needed for activation. If soil dries, flush for reactivation. Longer residual control than Bolero. Avoid drift to susceptible crops, especially tomatoes.</td>
</tr>
<tr>
<td>quinclorac</td>
<td>0.25 - 0.5 lb/A</td>
<td>Facet 75WP (see comments under preemergence applications)</td>
<td>See comments under preemergence applications. Delayed PREEMERGENCE application may provide greater residual control relative to flood establishment. Apply 1 - 5 days before rice emergence. Add 1 pt/A crop oil concentrate if weeds have emerged. See comments under PREEMERGENCE application.</td>
</tr>
<tr>
<td>quinclorac + thiobencarb</td>
<td>0.25 - 0.5 + 3.0 - 4.0 lbs/A</td>
<td>See comments above.</td>
<td>See comments above for each herbicide. See comments above on water management and variety susceptibility. Will broaden the spectrum of control relative to each herbicide applied above.</td>
</tr>
<tr>
<td>pendimethalin</td>
<td>0.75 - 1.0 lb/A</td>
<td>Prowl 3.3EC, 1.8 - 2.4 pts/A</td>
<td>Barnyardgrass, sprangletop, broadleaf signalgrass and crabgrass. Apply 1 - 5 days prior to emergence. Do not apply preplant incorporated or immediately after planting. Rice seed must have imbibed water before application. Apply only after rainfall or flushing for germination. Use low rates for coarse textured soil and high rates for fine textured clay soils.</td>
</tr>
<tr>
<td>quinclorac + pendimethalin</td>
<td>0.25 - 0.5 + 0.75 - 1.0 lb/A</td>
<td>See comments above.</td>
<td>See comments for each herbicide. See comments above on water management and possibly injury from Prowl. Will broaden the spectrum of control relative to each herbicide applied alone.</td>
</tr>
</tbody>
</table>

### EARLY POSTEMERGENCE

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Rate</th>
<th>Application Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>propanil</td>
<td>4 lbs/gal EC formulations</td>
<td>Barnyardgrass, fall panicum, Dry- or water-seeded rice. Weed foliage must be exposed. Better</td>
</tr>
</tbody>
</table>
propanil + molinate
2.25 - 3.0 + 2.25 - 3.0 lbs/A

3 - 4 qts/A
Various dry formulations

broadleaf
signalgrass, hemp sesbania,
northern jointvetch, rushes and annual sedges.

control on weeds with less than 4 leaves. Apply to small weeds.
Does not have residual activity and repeat applications may be needed.
Add crop oil concentrate at 1 qt/A to dry propanil formulations.
Applying propanil with Facet, Bolero or Prowl will improve grass control. Avoid drift to susceptible crops. NOTE: Some populations of barnyardgrass have developed resistance to propanil at rates as high as 30 lbs/A. Facet, Bolero and Prowl can control these populations when applied in a timely manner with appropriate water management.

Arrosolo
3 - 4 qts/A

Barnyardgrass, fall panicum, broadleaf signalgrass, hemp sesbania, northern jointvetch, rushes and annual sedge.

Apply to emerged weeds. Do not apply to rice that is not rooted in water-seeded systems. Provides better control than propanil if environmental conditions are marginal (moisture stress and low temperatures). Gives some residual weed control. Do not apply to Millie or Adair.
propanil +
pendimethalin
3 - 4 lbs/A + 0.75
- 1 lb/A

Liquid Propanil +
Prowl 3.3EC
3 - 4 qts/A + 1.8 - 2.4
pts/A

See comments for propanil +
thiobencarb.

Apply to emerged weeds not covered by water. Drain flood or any surface water before application. Rainfall or flushing will be needed for activation. Gives residual control for about 2 weeks. Residual control from Prowl may be reduced after flooding, flushing or several days of heavy rainfall. If used on water-seeded rice do not apply before the 3 - 4 leaf stage of rice.

quinclorac +
propanil
0.25 - 0.38 + 3 - 4
lbs/A

Facet + Liquid
Propanil 0.33 - 0.67
lb/A + 3 - 4 qts/A (see rate recommendations for Facet relative to soil type)

Barnyardgrass,
broadleaf
signalgrass,
morningglory,
hemp sesbania,
northern
jointvetch, rushes
and annual
sedges.

Apply to small actively growing weeds. Add crop oil concentrate at 1 qt/A if dry formulation of propanil is used. Rainfall or flushing may be required for activation or reactivation.

quinclorac
0.25 - 0.5 lb/A

Facet 75WP
0.33 - 0.67 lb/A
Add 1 qt/A crop oil.
See previous comments on rates relative to soil type.

Barnyardgrass,
morningglory,
hemp sesbania,
northern
jointvetch. Will not control sprangletop, nutseed or smartweed.

Apply to small actively growing weeds. Seed exposed to the spray may be injured. Add propanil if weeds exceed 1-in height. Rainfall or flushing may be required for activation or reactivation. Fields treated with Facet should be scouted for smartweed, nutseed and sprangletop and treated if necessary.

**EARLY POSTEMERGENCE (SPECIALTY USE)**

propanil +
bentazon
3 - 5 lbs + 0.75
lb/A

Liquid Propanil +
Basagran 3 - 5 pts/A +
1.5 pt/A

Annual grasses,
smartweed,
cocklebur,
redstem, yellow
nutseed,
dayflower and
spikerush. Will not control purple nutseed.

Apply to small annual grasses, broadleaf and aquatic weeds and nutseed. Propanil timing for grasses should be applied as for propanil alone. Add 1 qt/A crop oil concentrate if dry formulation of propanil is used. Dry- or water-seeded rice. No residual control. Control of yellow nutseed can be erratic.
<table>
<thead>
<tr>
<th></th>
<th>Londax 60DF</th>
<th>Ducksalad, redstem, eclipta, false pimpernel, gooseweed, dayflower, flatsedge, water hyssop and arrowhead.</th>
<th>Apply within 5 days after flooding and maintain flood at least 7 days. For water-seeded rice, apply as soon as possible after rice has pegged and flood has stabilized. Avoid pumping for 7 days after treatment, if possible. If weeds have emerged, add 1 qt/A crop oil concentrate.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POSTEMERGENCE (BROADLEAF AND AQUATIC WEED CONTROL AT MIDSEASON)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-D amine, MCPA or triclopyr</td>
<td>2,4-D amine or MCPA 2 - 3 pts/A of 4 lb/gal Grandstand 1 - 2 pts/A</td>
<td>Broadleaf and aquatic weed control.</td>
<td>Apply 2,4-D or MCPA between the first internode elongation (first green ring) and ( \frac{1}{2} ) inch long internode elongation (second green ring). Do not apply when internode exceeds ( \frac{1}{2} ) inch. Grandstand may be applied from the 3- to 4-leaf stage up to ( \frac{1}{2} ) inch internode elongation. Adhere to restrictions on 2,4-D application in north Louisiana.</td>
</tr>
<tr>
<td>1 - 1.5 lbs/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>acifluorfen</td>
<td>Blazer ½ - 1 pt/A Add a nonionic surfactant at 0.25%</td>
<td>Hemp sesbania (coffeebean).</td>
<td>When hemp sesbania is 1 - 5 feet tall. Do not apply past the boot stage of rice. May cause tipburn on rice, but symptoms will be quickly outgrown. Do not apply more than 1 pt/A per season. Do not apply within 45 days of harvest.</td>
</tr>
<tr>
<td>0.125 - 0.25 lb/A</td>
<td></td>
<td></td>
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<tr>
<td><strong>PREHARVEST</strong></td>
<td></td>
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</tr>
<tr>
<td>sodium chlorate</td>
<td>Several brands 2 gals/A of 3 lb/gal or 1 gal/A of 6 lb/gal</td>
<td>Desiccating green weed foliage.</td>
<td>When average moisture is 25% or below. Harvest within 7 days after application to prevent overdrying.</td>
</tr>
<tr>
<td>6 lbs/A</td>
<td></td>
<td></td>
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<tr>
<td><strong>RATOO CROP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-D</td>
<td>HiDep formulation currently only 2,4-D labeled. 1 - 2 pts/A</td>
<td>Most broadleaf weeds.</td>
<td>Apply within 2 weeks of first harvest and after flooding.</td>
</tr>
<tr>
<td>0.47 - 0.95 lb/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>triclopyr</td>
<td>Grandstand 1 pt/A</td>
<td>Hemp sesbania, jointvetch and other broadleaf weeds.</td>
<td>Apply within 2 weeks of first harvest</td>
</tr>
<tr>
<td>0.375 lb/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bentazon</td>
<td>Basagran 2 pts/A + crop oil concentrate</td>
<td>Sedges and some broadleaf weeds.</td>
<td>Apply to small weeds less than 8- to 10-inches tall.</td>
</tr>
</tbody>
</table>
Disease Management
Donald E. Groth, Milton C. Rush and Clayton A. Hollier

Introduction
Disease damage to rice can greatly impair productivity and sometimes destroy a crop. The United States does not have any of the destructive viral diseases present in other rice-growing areas of the world, but fungal diseases are prevalent and very destructive to Louisiana rice. Several bacterial diseases have been found, but no significant yield losses have been associated with them.

Direct losses to disease include reduction in plant stands, lodging, spotted kernels, fewer and smaller grains per plant, and a general reduction in plant efficiency. Indirect losses include the cost of fungicides used to manage disease, application costs and reduced yields associated with special cultural practices that reduce disease, but may not be conducive to producing maximum yields.

The major diseases of rice in the United States are the fungal diseases blast, caused by Pyricularia grisea (Figs. 54-57); stem rot, caused by Magnaporthe salvinii (Sclerotium oryzae) (Figs. 58, 59); sheath blight, caused by Thanatephorus cucumeris (Rhizoctonia solani) (Figs. 60-63); brown spot, caused by Cochiobolus miyabeanus (Fig. 64); narrow brown spot, caused by Sphaerulina oryzina (Cercospora jansseana) (Figs. 65, 66); and kernel smut, caused by Neovossia horrida (Fig. 67). Seedling diseases caused by species of Achlya and Pythium (Figs. 68, 69) also are important in water-seeded rice.

Minor diseases include crown rot (Fig. 70), causal agent unknown; leaf scald, caused by Gerlachia oryzae (Figs. 71, 73);
leaf smut, caused by Entyloma oryzae (Fig. 73); sheath rot, caused by Sarocladium oryzae (Fig. 74); stackburn disease, caused by Alternaria padwickii (Fig. 75); sheath spot, caused by Rhizoctonia oryzae (Figs. 76,77); crown sheath rot, caused by Gaumannomyces graminis var. graminis (Fig. 78); black kernel, caused by Curvularia lunata; seedling blights, caused by various fungi (Fig. 79); bacterial leaf blight (Fig. 80); false smut, caused by Ustilaginoidea virens (Fig. 81); root rots, caused by several fungi; and several miscellaneous leaf, stem and glume spotting diseases. Several diseases caused by sclerotial fungi are also found in Louisiana but are not significant.

A disorder known as panicle blight (Fig. 82) has become increasingly important. Little is known about its cause.

An undefined pathogen complex acting alone or with insect damage (feeding) also causes the grain and kernel discoloration called “pecky” rice (Fig. 108).

The physiological disorders straighthead (Fig. 83) and bronzing or zinc deficiency (Fig. 32) occur throughout the southern rice area and are locally severe. Cold injury (Fig. 84), salt damage (Fig. 85) and nutrient deficiencies often mimic disease symptoms.

Two minor diseases of rice in Louisiana are caused by small parasitic round worms called nematodes. These are white tip, caused by Aphelenchoides besseyi (Fig. 86), and root knot, caused by Meloidogyne species (Fig. 87).

The first step toward disease management is identification followed by careful field scouting. Diseases known to occur in Louisiana and their causal agents are listed in Table 10. A guide for rapid identification of the major diseases is given in the following section (Table 11). Knowing the level of resistance of the variety to major diseases can be useful in determining the probability of having problems warranting preventive management measures. Commercial varieties and their resistance levels to major diseases are in Table 12. Scouting information or disease thresholds and management information are summarized for the major diseases in Table 13.

Use of foliar fungicides to manage rice diseases is often justified under severe disease conditions. Some factors which affect the probability of fungicide use being warranted include disease history in the field, the resistance of the variety, the yield potential, use (seed or grain), date of planting and ratoon crop potential. Always follow label directions. Since the list of labeled fungicides may change, contact your Cooperative Extension Service agent for current information on fungicides available for rice disease management.

Rice Disease Identification

Each year the Louisiana rice crop is affected by many diseases. Severity of symptoms often varies because of varietal resistance, environmental conditions and plant growth stage. Also, not all symptoms typical of a disease occur on a single plant. It is important to look at several plants, from all over the field, to establish an accurate diagnosis. In the text, all symptoms known to occur are described, but not all will be expressed. Use the guide to the identification of rice diseases present in Louisiana to decide which diseases are present. The diseases are divided into sections based on what plant part is affected. Several diseases may affect more than one part of a rice plant, however. When a disease is identified, more information is in the text and in Table 13.
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Pathogen name or cause</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial diseases</strong></td>
<td></td>
</tr>
<tr>
<td>Bacterial blight</td>
<td>Xanthomonas oryzae pv. oryzae (Ishiyama) Swings et al. = X. campestris pv. oryzae (Ishiyama) Dye</td>
</tr>
<tr>
<td>Foot rot</td>
<td>Erwinia chrysanthemi Burkholder et al.</td>
</tr>
<tr>
<td>Pecky rice (kernel spotting)</td>
<td>Damage by bacteria (see also under fungal and miscellaneous diseases)</td>
</tr>
<tr>
<td><strong>Fungal diseases</strong></td>
<td></td>
</tr>
<tr>
<td>Black kernel</td>
<td>Curvularia lunata (Wakk.) Boedijn (teleomorph: Cochliobolus lunatus R.R. Nelson &amp; Haasis)</td>
</tr>
<tr>
<td>Blast (leaf, neck [rotten neck], nodal and collar)</td>
<td>Pyricularia grisea Sacc.=P. oryzae Cava (teleomorph: Magnaporthe grisea (Hebert) Barr)</td>
</tr>
<tr>
<td>Brown spot</td>
<td>Cochliobolus miyabeansus (Ito &amp; Kuribayashi) Drechs. ex Dastur (anamorph: Bipolaris oryzae (Breda de Haan) Shoemaker)</td>
</tr>
<tr>
<td>Crown sheath rot</td>
<td>Gaeumannomyces graminis (Sacc.) Arx &amp; D. Olivier</td>
</tr>
<tr>
<td>Downy mildew</td>
<td>Sclerophthora macrospora (Sacc.) Thirumalachar et al.</td>
</tr>
<tr>
<td>Eyespot</td>
<td>Drechslera gigantea (Heald &amp; F.A. Wolf) Ito</td>
</tr>
<tr>
<td>False smut</td>
<td>Ustilaginoidea virens (Cooke) Takah.</td>
</tr>
<tr>
<td>Kernel smut</td>
<td>Tilletia barclayana (Bref.) Sacc. &amp; Syd. in Sacc. = Neovossia horrida (Takah.) Padwick &amp; A. Khan</td>
</tr>
<tr>
<td>Leaf smut</td>
<td>Entyloma oryzae Syd. &amp; P. Syd.</td>
</tr>
<tr>
<td>Leaf scald</td>
<td>Microdochium oryzae (Hashioka &amp; Yokogi) Samuels &amp; I.C. Hallet = Rhynchosporium oryzae Hashioka &amp; Yokogi</td>
</tr>
<tr>
<td>Narrow brown leaf spot</td>
<td>Cercospora janseana (Racib.) O. Const. = C. oryzae Miyake (teleomorph: Sphaerulina oryzina K. Hara)</td>
</tr>
<tr>
<td>Pecky rice (kernel spotting)</td>
<td>Damage by many fungi including Cochliobolus miyabeansus (Ito &amp; Kuribayashi) Drechs. ex Dastur, Curvularia spp., Fusarium spp., Microdochium oryzae (Hashioka &amp; Yokogi) Samuels &amp; I.C. Halett,</td>
</tr>
</tbody>
</table>
Sarocladium oryzae (Sawada) W. Gams & D. Hawksworth and other fungi

Root rots
Fusarium spp., Pythium spp., P. dissotocum Drechs., P. spinosum Sawada

Seedling blight
Cochliobolus miyabeanus (Ito & Kuribayashi) Drechs. ex Dastur, Curvularia spp., Fusarium spp., Rhizoctonia solani Kuhn, Sclerotium rolfsii Sacc. (teleomorph: Athelia rolfsii (Curzi) Tu & Kimbrough), and other pathogenic fungi.

Sheath blight
Thanatephorus cucumeris (A.B. Frank) Donk (anamorph: Rhizoctonia solani Kuhn)

Sheath rot
Sarocladium oryzae (Sawada) W. Gams & D. Hawksworth
= Acrocylindrium oryzae Sawada

Sheath spot
Rhizoctonia oryzae Ryker & Gooch

Stackburn (Alternaria leaf spot)
Alternaria padwickii (Ganguly) M.B. Ellis

Stem rot
Magnaporthe salvinii (Cattaneo) R. Krause & Webster (synanamorphs: Sclerotium oryzae Cattaneo, Nakataea sigmoidae (Cavara) K. Hara)

Water-mold (seed-rot and seedling disease)
Achlya conspicua Coker, A. klebsiana Pieters, Fusarium spp., Pythium spp., P. dissotocum Drechs., P. spinosum Sawada

**Disorders**

Bronzing
Zinc deficiency

Cold injury
Low temperatures

Panicle blight
Cause undetermined

Pecky rice (kernel spotting)
Feeding injury by rice stink bug

Straighthead
Arsenic induced, unknown physiological disorder

**Nematodes**

Root-knot
Meloidogyne spp.

White tip
Aphelenchoides besseyi Christie
FIGURES
LOUISIANA RICE
PRODUCTION HANDBOOK
Figure 1. Germination

Figure 2. Coleoptile and radicle development

Figure 3. Mesocotyl development

Figure 4. Primary leaf

Figure 5. Primary leaf elongates

Figure 6. Sheath, collar and blade

Figure 7. First leaf

Figure 8. Second leaf
Figure 9. Shoot and root parts

Figure 10. First primary tiller

Figure 11. Second primary tiller

Figure 12. Crown and modes

Figure 13. Green ring

Figure 14. Second internode

Figure 15. Panicle differentiation
Figure 33. Seedling barnyardgrass
Figure 34. Barnyardgrass
Figure 35. Broadleaf signalgrass
Figure 36. Red rice
Figure 37. Hemp sesbania
Figure 38. Hemp sesbania
Figure 39. Alligatorweed
Figure 40. Dayflower
Figure 82. Panicle blight

Figure 83. Straighthead

Figure 84. Cold injury

Figure 85. Salt injury

Figure 86. White tip

Figure 87. Root knot

Figure 88. Downy mildew

Figure 89. Seed midge tubes
Figure 102. Rice stem borer larva

Figure 103. Sugarcane borer larva on rice

Figure 104. Stalkborer injury

Figure 105. Stalkborer (white-head condition)

Figure 106. Rice stink bug adult

Figure 107. Rice stink bug adult

Figure 108. Pecky rice

Figure 109. Skipper larva

Figure 110. Skipper adult
Table 11. A guide to the identification of rice diseases present in Louisiana

For identification of the major diseases, determine the part of the plant affected by the disease then refer to that section of Table 11. A list of the causal agents of all rice diseases known to occur in Louisiana is in Table 10.

I. Planted Seeds and Seedlings
Water-seeded rice: seeds rotted after draining water from field, copper or greenish-brown spots on soil surfaces around or above rotted seeds; coarse, bristly mycelium radiating from seed (Achlya spp.) (Fig. 68) or gelatinous matrix surrounding each affected seed (Pythium spp.) (Fig. 69). Water Mold.

Water-seeded rice: seedlings 1 to 4 inches tall dying in seedling flood or after flushing seeded field. Pythium Seedling Blight.

Drill-seeded or dry broadcast rice: seedlings 1 to 4 inches tall dying:

a) Brown spot on coleoptile or growing point (Fig. 79), seedlings suddenly dying. Seedling Blight.

b) Seedlings dying or turning white in patches or in short strips of drill row; fluffy white mycelium and small, round sclerotia (tan) may be present on soil surface at the base of affected seedlings after flushing seeded field. Sclerotium Seedling Blight.

Seedlings at three- to five-leaf stage dying, often in patches, may have linear reddish-brown lesion on sheath of small seedlings, older seedlings with purple-brown blotches made up of small spots aggregating, leaves yellow or bronze (Fig. 32), lower leaves floating on surface of flood water; seedlings dying in deeper water and disappearing below surface of water. Bronzing.

See also Salinity and Cold Injury.

II. Roots and Crown (Root-Stem Interface)
Crown area decayed with soft rot, black or dark brown with streaks extending to the lower internodes of culms (Fig. 70), fetid odor of bacterial soft rot, tillers dying one at a time; roots dying and turning black, adventitious roots produced at node above crown area. A similar discoloration of the crown may be caused by applying hormonal herbicide such as 2,4-D too early. Crown Rot.

Roots turning black or brown, decayed, reduced root volume, roots dying. Root Rot.

Roots with swollen areas, found only under dry-land conditions (Fig. 87). Root knot.

III. Leaf Blades
Lesions varying from small round, dark-brown spots, to oval spots with narrow reddish-brown margin and gray or white center with dark circular line (eyespot lesion) (Fig. 54), spots becoming elongated, diamond-shaped or linear with gray dead area in center surrounded by narrow reddish-brown margin. Leaf Blast.

Round to oval, dark-brown lesions with yellow or gold halo (Fig. 64); as lesions enlarge, they remain round, with center area necrotic, gray and lesion margin reddish-brown to dark brown. Brown Spot.
Long, narrow brown or reddish-brown lesion (Fig. 65); lesions 0.5 to 3 cm long, parallel with leaf veins, and usually restricted to the area between veins; lesions may occur on leaf sheaths. **Narrow Brown Leaf Spot.**

Lesions consist of alternating wide bands of white, greenish-gray or tan with narrow bands of reddish-brown or brown (Fig. 63); lesions begin at base of blade, spreading from leaf sheath or from infection point on leaf blade. **Sheath Blight.**

Lesions consist of wide bands of gray, dying tissue alternating with narrow reddish-brown bands (Fig. 71); band pattern in chevrons from leaf tip or edges of the leaf, sometimes lesions are gray blotches at leaf edge with reddish-brown margin, advancing edge of lesion usually has a yellow or gold area (Fig. 72) between reddish-brown margin and green, healthy tissues. **Leaf Scald.**

Small 1-2 mm, black linear lesions on leaf blade (Fig. 73), usually more lesions on upper half of the leaf blade, lesions may have dark gold or light brown halo, leaf tip dries as plants approach maturity, lesions on sheaths of upper leaves. **Leaf Smut.**

Round or oval white or pale tan spot with narrow red or reddish-brown margin (Fig. 75); often two adjacent spots coalesce to form an oval double spot; lesions are from 0.5 to 1 cm in diameter, spots with small black fruiting structures in the center. **Stackburn.**

Leaf tips turn white with a yellow area between the white tip and the healthy green area (Fig. 86); white areas sometimes occur on leaf edges; flag leaf blade twisted with poor emergence of the panicle; kernels aborted or poorly filled; grain distorted or discolored. **White Tip.**

Lesions consist of elongated lesions near the leaf tip or margin and start out water soaked in appearance; lesions, several inches long, turn white to yellow and then gray because of saprophytic fungi (Fig. 80). **Bacterial Leaf Blight.**

**IV. Leaf Sheath and Stem**

Water-soaked, gray-green lesion at water line (Fig. 60) during tillering or early jointing stages of growth, lesions becoming oval, white or straw-colored in center with reddish-brown edge (Fig. 62), lesions 1 - 2 cm wide and 3 - 4 cm long, lesions spreading up leaf sheaths and onto leaf blades, lesions discrete or forming a continuous band on sheath (Fig. 62) or leaf (Fig. 63) of alternating wide necrotic areas with narrow reddish-brown bands. **Sheath Blight.**

Black, angular lesions on leaf sheaths at water line on plants at tillering or early jointing stages of growth (Fig. 58); at later stages outer sheath drying, inner sheath discolored or with black angular lesion; culms discolored with dark-brown or black streaks; raised areas of dark fungus mycelium on surface; gray mycelium inside of culm or at maturity culm collapsed with small, round black sclerotia in dead sheath tissues and inside of culm (Fig. 59). **Stem Rot.**

Lesions oval, pale green, turning cream or white in the center with a broad dark reddish-brown margin (Fig. 76, 77). Lesions remain separate, not forming large continuous lesions. **Sheath Spot.**
Black to brown diffuse lesions on the sheath near the water line (Fig. 78). Perithecia necks protruding from upper surface and a thick fungal mat between leaf sheath and culm. **Crown Sheath Rot.**

Reddish- or purple-brown, netlike pattern on sheath below the collar of lower leaf blades (Fig. 66), lesion oval. 1 to 2 cm wide and 3 to 5 cm long, leaf blades turning yellow and drying. **Cercospora Net Spot.** (See Narrow Brown Leaf Spot.)

General reddish discoloration of flag leaf sheath or reddish-brown or yellow-tan spots with dark, irregular ring pattern inside of spots (Fig. 74); panicles emerging poorly; stem of panicle twisted; white “frosting” of conidia on inside of leaf sheath, florets of panicles on affected tillers discolored a uniform reddish-brown or dark brown. Grain does not fill or kernels are lightweight. **Sheath Rot.**

Narrow red-brown lesions on flag leaf sheath or penultimate leaf sheath after panicles emerge; lesions 0.5 to 1.5 mm wide and up to 1 to 3 cm long; lesions run parallel with veins in sheaths, affecting the tissues between veins (Fig. 66). **Narrow Brown Leaf Spot.**

Collar of flag leaf discolored brown or chocolate-brown; leaf blade detaches from sheath as lesion dies and dries (Fig. 56). **Blast on Flag Leaf Collar.**

Culm nodes turn black or nodes become shriveled and gray as plants approach maturity (Fig. 55); nodes purple to blue-gray with conidia of the pathogen; culms and leaves straw-colored above affected node; culms lodge at affected nodes. **Node Blast.**

**V. Panicle, Florets and Grain**

Panicle

Node and surrounding area at base of panicle discolored brown or chocolate-brown (Fig. 57); stem of panicle shrivels and may break; node purplish or blue-gray with conidia of the fungal pathogen; panicle white or gray; florets do not fill and turn gray; panicle branches and stems of florets gray-brown lesions. **Rotten Neck Blast.**

Panicles upright, not falling over or slightly bent over because of sterility. Hulls distorted, beak-shaped. Plants may not head at all (Fig. 83). **Straighthead.**

Internodal area above or below node at the base of the panicle turns light brown or tan-brown; affected area dies and shrivels; kernels in florets of lower portion of the panicle do not fill. **Neck Blight.** (See Brown Spot and Narrow Brown Leaf Spot for more information.)

Single florets or several florets on a panicle branch turn light brown or straw-colored; floret stem with brown lesion; grain stops developing; florets turn gray. **Panicle Blast.**

Panicles irregular; unable to emerge from the leaf sheath, and becoming twisted (Fig. 88); the panicle is small, normally remaining green longer than usual; no seeds produced. **Downy Mildew.**
Panicles small, reduced number of spikelets, and lemmas and paleas often absent on terminal portions of panicles. **White Tip.**

**Florets and Grain**

Single florets or several florets per panicle with brown, reddish-brown, purple or white surrounded by purple-brown spots (Fig. 108). **Grain Spotting or Pecky Rice.**

Maturing grain partially filled with or without grayish cast; powdery black mass on surface of the kernel and at seam between palea and lemma (Fig. 67) (rubs off easily onto fingers). **Kernel Smut.** See black kernel.

Single florets or more commonly several florets in a panicle turn reddish-brown to dark brown. **Sheath Rot.**

Single florets or several florets on a panicle branch turn light brown or straw-colored (Fig. 82). The grain stops developing, and the florets turn gray. **Panicle Blight.**

Maturing grain partially filled, shriveled, chalky, fuzzy black mass covering surface of the grain or at seam between palea and lemma (will not easily rub off on fingertips). **Brown Spot.**

Large orange fruiting structure on one or two grains in maturing panicle; when orange membrane ruptures, a mass of greenish-black spores is exposed (Fig. 81); grain replaced by one or more sclerotia. **False Smut.**

**Rice Diseases in Louisiana**

**Bacterial Leaf Blight**

Bacterial leaf blight is caused by the bacterium *Xanthomonas campestris* pv. *oryzae*. It was first identified in the United States in Texas and Louisiana in 1987. No major losses have been associated with this disease in the United States, but bacterial leaf blight in other parts of the world causes severe damage.

The blight bacterium overwinters in rice debris in the soil and on weed hosts. There is also a slight chance that seed may transmit the pathogen. The pathogen is spread by wind-blown rain, irrigation water, plant contact and probably on plant debris on machinery. High humidity and storms favor disease development. Water-soaked areas appear on the leaf margins near the tips, enlarge and turn white to yellow. As the lesions mature, they expand, turn white and then gray because of growth of saprophytic fungi (Fig. 80). The lesion may be several inches long.

Contact your Cooperative Extension Service agent if you suspect this disease. Accurate identification is important since the symptoms can be confused with other diseases, especially leaf scald, herbicide damage and other plant stress.

Management practices include rotating to nongrass crops, tilling to destroy plant debris and avoiding contaminating the field through infected plant materials or irrigation water.

**Black Kernel**

The fungus *Curvularia lunata* causes black kernel. The fungus causes severe grain discoloration, and after milling the kernels appear black. When infections are heavy, the fungus can cause seedling blights or weakened seedlings. This disease is rarely severe enough that management practices are recommended. Seed treatments to manage other diseases should reduce seedling damage. No other management measures are warranted.
Rice blast is caused by the fungus *Pyricularia grisea*. The disease is also called leaf blast, node blast, panicle blast, collar blast and rotten neck blast, depending on the portion of the plant affected. Blast has been one of the most important diseases in Louisiana, causing severe yield losses to susceptible varieties under favorable environmental conditions.

Blast can be found on the rice plant from the seedling stage to near maturity. The leaf blast phase occurs between the seedling and late tillering stages. Spots on leaves start as small white, gray or blue tinged spots, which enlarge quickly under moist conditions to either oval diamond-shaped spots or linear lesions with pointed ends with gray or white centers and narrow brown borders (Fig. 54). Leaves and whole plants are often killed under severe conditions. Lesions on resistant plants are small brown specks that do not enlarge.

On stem nodes (Fig. 55), the host tissue turns black and becomes shriveled and gray as the plant approaches maturity. The infected area may turn dark purple to blue-gray because of the production of fungal spores. Culms and leaves become straw-colored above the infected node. Plants lodge or break off at the infected point, or they are connected only by a few vascular strands. Some varieties are infected where the flag leaf attaches to the sheath at the collar (Fig. 56). The lesion turns brown or chocolate brown to gray, and the flag leaf becomes detached from the plant as the lesion area becomes dead and dry.

Rotten neck symptoms appear at the base of the panicle starting at the node (Fig. 57). The tissue turns brown to chocolate brown and shrivels, causing the stem to snap and lodge. If the panicle does not fall off, it may turn white to gray, or the florets that do not fill will turn gray. Panicle branches and stems of florets also have gray-brown lesions.

Scouting a field for blast should begin early in the season during the vegetative phase and continue through the season to heading. Leaf blast will usually appear in the high areas of the field where the flood has been lost or is shallow. Areas of heavy nitrogen fertilization and edges of the fields are also potential sites of infection. If leaf blast is in the field or has been reported in the same general area, and if the variety is susceptible, fungicidal applications are advisable to reduce rotten neck blast.

The pathogen overwinters as mycelium and spores on infected straw and seed. Spores are produced from specialized mycelium called conidiophores and become windborne at night on dew or rain. The spores are carried by air currents and land on healthy rice plants. The spores germinate under high humidity and dew conditions and infect the plant. Generally lesions will appear four to seven days later, and additional spores are produced. Plants of all ages are susceptible. Medium grain varieties are more susceptible to blast, especially during the leaf phase, than the long grain varieties grown in Louisiana.

Environmental conditions that favor disease development are long dew periods, high relative humidity and warm days with cool nights. Agronomic practices that favor disease development include excessive nitrogen levels, late planting and dry soil (loss of flood). Several physiologic races of *P. grisea* exist, and disease development varies, depending on variety-race interactions.

The disease can be reduced by planting resistant varieties (Table 12), maintaining a 4- to 6-inch flood (Kim, 1986), proper nitrogen fertilizer, avoiding late planting and by applying a fungicide recommended by the Louisiana Cooperative Extension Service.

Brown spot

Brown spot, caused by the fungus *Cochiobolus miyabeanus*, is one of the most prevalent rice diseases in Louisiana. It is also called Helminthosporium leaf spot. When *C. miyabeanus* attacks the plants at emergence, the resulting seedling blight causes sparse or inadequate stands and weakened plants. Leaf spots are present on young rice, but the disease is
more prevalent as the plants approach maturity and the leaves begin to senesce. Yield losses from leaf infection or leaf spots are probably not serious. When the fungus attacks the panicle, including the grain, economic losses occur. Heavy leaf spotting indicates an unfavorable growth factor; usually a soil problem.

The pathogen also attacks the coleoptiles, leaves, leaf sheath, branches of the panicle, glumes and grains. The fungus causes brown, circular to oval spots on the coleoptile leaves of the seedlings (Fig. 79). It may cause seedling blight.

Leaf spots are found throughout the season. On young leaves, the spots are smaller than those on older leaves. The spots may vary in size and shape from minute dark spots to large oval to circular spots (Fig. 64). The smaller spots are dark brown to reddish-brown. The larger spots have a dark brown margin and a light, reddish-brown or gray center. The spots on the leaf sheath and hulls are similar to those on the leaves.

The fungus attacks the glumes and causes a general black discoloration. It also attacks the immature florets, resulting in no grain development or kernels that are lightweight or chalky.

Brown spot is an indicator of unfavorable growth conditions including insufficient nitrogen, inability of the plants to use nitrogen because of rice water-weevil injury, root rot or other unfavorable soil conditions. As the plants approach maturity, brown spot becomes more prevalent, and the spots are larger on senescing leaves.

Damage from brown spot can be reduced by maintaining good growing conditions for rice by proper fertilization, crop rotation, land leveling, proper soil preparation and water management. Seed-protectant fungicides reduce the severity of seedling blight caused by this seedborne fungus. Some varieties are less susceptible than others (Table 12).

**Crown Rot**

Crown rot is suspected to be caused by a bacterial infection (possibly Erwinia chrysanthemi). It is a minor disease usually associated with the variety Saturn. Symptoms first appear during tillering. The crown area is decayed, with soft rotting, becoming black or dark brown with discolored streaks extending into the lower internodes of culms (Fig. 70). There is a fetid or putrid odor characteristic of bacterial soft rots, and tillers start dying one at a time. The roots also die and turn black. Adventitious roots are produced at the node above the crown area. A similar discoloration of the crown can be caused by misapplied herbicides. Control practices are not available.

**Crown Sheath Rot**

Crown sheath rot is caused by the fungus Gaeumannomyces graminis var. graminis. Other names for this disease include brown sheath rot, Arkansas foot rott and black sheath rot. It has been considered a minor disease of rice, but recent reports from Texas suggest severe damage can occur. The pathogen kills lower leaves, thus reducing photosynthetic activity, causes incomplete grain filling and plants can lodge.

Symptoms appear late in the season, usually after heading. Sheaths on the lower part of the rice plant are discolored brown to black (Fig. 78). Reddish-brown mycelial mats are found on the inside of infected sheaths. Dark perithecia are produced within the outside surface of the sheath. Perithecia are embedded in the sheath tissues with beaks protruding through the epidermis. This disease can easily be confused with stem rot (Fig. 58).

The fungus survives as perithecia and mycelia in plant residues. Ascospores are windborne in moist conditions. The fungus has been reported to be seedborne. Management practices have not been worked out for this disease.

**Downy Mildew**

Downy mildew is caused by the fungus Sclerophthora macrospora. In early growth stages, infected seedlings are dwarfed and twisted with chlorotic, yellow to whitish spots. Symptoms are more severe on the head (Fig. 88). Because of failure to emerge, panicles are distorted, causing
irregular, twisted and spiral heads that remain green longer than normal. No control measures are recommended.

**False Smut**

False smut, caused by the fungus *Ustilaginoidea virens*, is a minor disease in the United States. The disease is characterized by large orange to brown-green fruiting structures on one or more grains of the mature panicle (Fig. 81). When the orange covering ruptures, a mass of greenish-black spores is exposed. The grain is replaced by one or more sclerotia. All varieties appear to have a high level of resistance, and disease control measures are not required.

**Grain Spotting and Pecky Rice**

Many fungi infect developing grain and cause spots and discoloration on the hulls or kernels. Damage by the rice stink bug, *Oebalus pugnax* F., also causes discoloration of the kernel. Kernels discolored by fungal infections or insect damage are commonly called pecky rice (Fig. 108). This is complex disorder involves many fungi, the white-tip nematode and insect damage. High winds at the early heading stage may cause similar symptoms. Proper insect control and disease management will reduce this problem.

**Kernel Smut**

This fungal disease is caused by *Neovossia barclayana*. Symptoms are observed at or shortly before maturity. A black mass of smut spores replaces all or part of the endosperm of the grain. The disease is easily observed in the morning when dew is absorbed by the smut spores. The spore mass expands and pushes out of the hull, where it is visible as a black mass (Fig. 67). When this spore mass dries, it is powdery and comes off easily on fingers. Rain washes the black spores over adjacent parts of the panicle. Affected grains are a lighter, slightly grayish color compared with normal grain.

Usually only a few florets may be affected in a panicle, but fields have been observed in Louisiana with 20 percent to 40 percent of the florets affected on 10 percent or more of the panicles in a field. Smutted grains produce kernels with black streaks or dark areas. Milled rice has a dull or grayish appearance when smutted grains are present in the sample. Because fewer kernels break when parboiled rice is milled, kernel smut can be a severe problem in processed rice. Growers are docked in price for grain with a high incidence of smut.

This disease is usually minor in Louisiana, but it can become epidemic in local areas. Some varieties are more susceptible and should be avoided where smut is a problem. Spores of the fungus are carried on affected seeds and overwinter in the soil of affected fields. The pathogen attacks immature, developing grain and is more severe when rains are frequent during flowering. Specific control measures are not available.

**Leaf Scald**

This disease, caused by *Gerlachia oryzae*, is common and sometimes severe in Central and South America. It is present in the southern rice area of the United States and in Louisiana annually. It affects leaves, panicles and seedlings. The pathogen is seedborne and survives between crops on infected seeds. The disease usually occurs on maturing leaves. Lesions start on leaf tips or from the edges of leaf blades. The lesions have a chevron pattern of light (tan) and darker reddish-brown areas (Fig. 71). The leading edge of the lesion usually is yellow to gold (Fig. 72). Fields look yellow or gold. Lesions from the edges of leaf blades have an indistinct, mottled pattern. Affected leaves dry and turn straw-colored.

Panicle infestations cause a uniform light to dark, reddish-brown discoloration of entire florets or hulls of developing grain. The disease can cause sterility or abortion of developing kernels.

Control measures are not recommended, but foliar fungicides used to manage other diseases have activity against this disease.
Leaf Smut

Leaf smut, caused by the fungus Entyloma oryzae, is a widely distributed, but somewhat minor, disease of rice. The fungus produces slightly raised, black spots (sori) on both sides of the leaves (Fig. 73) and on sheaths and stalks. The blackened spots are about 0.5 - 5.0 mm long and 0.5 - 1.5 mm wide. Many spots can be found on the same leaf, but they remain distinct from each other. Heavily infected leaves turn yellow, and leaf tips die and turn gray. The fungus is spread by airborne spores and overwinters on diseased leaf debris in soil.

Leaf smut occurs late in the growing season and causes little or no loss. Control measures are not recommended.

Narrow Brown Leaf Spot

Narrow brown leaf spot, caused by the fungus Cercospora janseana, varies in severity from year to year and is more severe as rice plants approach maturity. Leaf spotting may become very severe on the more susceptible varieties and causes severe leaf necrosis. Some premature ripening, yield reduction and lodging occur.

Symptoms include short, linear, brown lesions most commonly found on leaf blades (Fig. 65). Symptoms also occur on leaf sheaths, pedicels and glumes. Leaf lesions are 2-10 mm long and about 1 mm wide, tend to be narrower, shorter and darker brown on resistant varieties and wider and lighter brown with gray necrotic centers on susceptible varieties. On upper leaf sheaths, symptoms are similar to those found on the leaf. On lower sheaths, the symptom is similar to a “net blotch” or Cercospora sheath spot in which cell walls are brown and intracellular areas are tan to yellow (Fig. 66).

The primary factors affecting disease development are (1) susceptibility of varieties to one or more prevalent pathogenic races, (2) prevalence of pathogenic races on leading varieties and (3) growth stage. Although rice plants are susceptible at all stages of growth, the plants are more susceptible from panicle emergence to maturity.

Plant breeders have found differences in susceptibility among rice varieties (Table 12), but resistance is an unreliable control method because new races develop readily. Some fungicides used to reduce other diseases also may have activity against narrow brown leaf spot. Low nitrogen levels favors development of this disease.

Root Knot

Species of the nematode Meloidogyne cause root knot. Symptoms include enlargement of the roots and the formation of galls or knots (Fig 87). The swollen female nematode is in the center of this tissue. Plants are dwarfed, yellow and lack vigor. The disease is rare and yield losses low. The nematode becomes inactive after prolonged flooding.

Root Rot

Root rots are caused by several fungi including Pythium spinosum, P. dissotocum, other Pythium spp. and several other fungi. The rice plant is predisposed to this disorder by a combination of factors including physiological disorders, insect feeding, especially feeding of rice water weevil larvae, extreme environmental conditions and various other pathogens.

Symptoms can be noted as early as emergence. Roots show brown to black discoloration and necrosis. As the roots decay, nutrient absorption is disrupted, the leaves turn yellow and the plants lack vigor. With heavy root infections, plants lack support from the roots and lodge, causing harvest problems. Often plants with root rot show severe brown leaf spot infection. The disease is referred to as feeder root necrosis when the small fine roots and root hairs are destroyed. When this happens, no lodging occurs and symptom development is not as apparent on the upper plants.

Fertilizer usually reduces the above-ground symptoms although actual nutrient use is impaired. Rice water weevil control greatly reduces root rots. Draining fields stimulates root growth but can cause
problems with blast, weeds or efficiency of nutrient use.

Seedling Blight

Seedling blight, or damping off, is a disease complex caused by several seedborne and soilborne fungi including species of Cochliobolus, Curvularia, Sarocladium, Fusarium, Rhizoctonia and Sclerotium. Typically, the rice seedlings are weakened or killed by the fungi. Environmental conditions are important in disease development. Cold, wet weather is the most detrimental.

Seedling blight causes stands of rice to be spotty, irregular and thin. Fungi enter the young seedlings and either kill or injure them. Blighted seedlings that emerge from the soil die soon after emergence. Those that survive generally lack vigor, are yellow or pale green and do not compete well with healthy seedlings.

Severity and incidence of seedling blight depend on three factors: (1) percentage of the seed infested by seedborne fungi, (2) soil temperature and (3) soil moisture content. Seedling blight is more severe on rice that has been seeded early when the soil is usually cold and damp. The disadvantages of early seeding can be partially overcome by seeding at a shallow depth. Conditions that tend to delay seedling emergence favor seedling blight. Some blight fungi that affect rice seedlings at the time of germination can be reduced by treating the seed with fungicides.

Seeds that carry blight fungi frequently have spotted or discolored hulls, but seed can be infected and still appear to be clean. Cochliobolus miyabeanus, one of the chief causes of seedling blight, is seedborne. A seedling attacked by this fungus has dark areas on the basal parts of the first leaf (Fig. 79).

If rice seed is sown early in the season, treating the seed is likely to mean the difference between getting a satisfactory stand or having to plant a second time. Little benefit is received from treating rice seed to be sown late in the season, unless unfavorable weather prevails.

The soilborne seedling blight fungus, Sclerotium rolfsii, kills or severely injures large numbers of rice seedlings after they emerge when the weather at emergence is humid and warm. A cottony white mold develops on the lower parts of affected plants. This type of blight can be checked by flooding the land immediately.

Treatment of the seed with a fungicide is recommended to improve or ensure stands. Proper cultural methods for rice production, such as proper planting date or shallow seeding of early planted rice, will reduce the damage from seedling blight fungi.

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Sheath Blight

Sheath blight has been the most economically significant disease in Louisiana since the early 1970s. The disease is caused by Rhizoctonia solani, a fungal pathogen of both rice and soybeans. On soybeans, it causes the aerial blight disease.

Several factors have contributed to the development of sheath blight from minor to major disease status. They include the increased acreage planted to susceptible long-grain varieties, the increase in the acreage of rice grown in rotation with soybeans, the increased use of broadcast seeding and the higher rates of nitrogen fertilizers used with the modern commercial rice varieties. The disease is favored by dense stands with a heavily developed canopy, high temperature and high humidity.
Sheath blight is characterized by large oval spots on the leaf sheaths (Fig. 62) and irregular spots on leaf blades (Fig. 63). Infections usually begin during the late tillering-joint elongation stages of growth. The fungus survives between crops as structures called sclerotia or as hyphae in plant debris. Sclerotia (Fig. 61) or plant debris floating on the surface of irrigation water serves as sources of inoculum that attack and infect lower sheaths of rice plants at the waterline. Lesions about 0.5 - 1 cm in width and 1 - 3 cm in length are formed a little above the waterline on infected culms (Fig. 60). Fungus mycelium grows up the leaf sheath, forms infection structures, infects and causes new lesions. The infection can spread to leaf blades (Fig. 63). The lower leaf sheaths and blades are affected during the jointing stages of growth. After the panicle emerges from the boot, the disease progresses rapidly to the flag leaf on susceptible varieties. With very susceptible varieties, the fungus will spread into the culm from early sheath infections. Infected culms are weakened, and the tillers may lodge or collapse.

The fungus can spread in the field by growing from tiller to tiller on an infected plant or across the surface of the water to adjacent plants. The fungus also grows across touching plant parts, for example from leaf to leaf, causing infections on nearby plants. Infected plants are usually found in a circular pattern in the field because the fungus does not produce spores and must grow from plant to plant. The lesions have grayish-white or light green centers with a brown or reddish-brown margin (Fig. 63). As lesions coalesce on the sheath, the blades turn yellow-orange and eventually die. As areas in the field with dead tillers and plants increase, they may coalesce with other affected areas to cause large areas of lodged, dead and dying plants. Damage is usually most common where wind-blown, floating debris accumulates in the corners of cuts when seedbeds are prepared in the water.

Sheath blight also affects many grasses and weeds other than rice, causing similar symptoms. Sclerotia that survive between crops are formed on the surface of lesions on these weed grasses, as well as on rice and soybeans. The sclerotia are tightly woven masses of fungal mycelium covered by an impervious, hydrophobic coating secreted by the fungus.

Disease severity can be reduced by integrating several management practices. Dense stands and excessive use of fertilizer both tend to increase the damage caused by this disease. Broadcast seeding tends to increase stand and canopy density. Rotation with soybeans or continuous rice increases the amount of inoculum in field soils. Fallow periods, with disking to control growth of grass weeds, will reduce inoculum in the soil. The pathogen also is known to infect sorghum, corn and sugarcane when environmental conditions are favorable for disease development.

Medium grain rice varieties are more resistant to sheath blight than most of the long grain varieties. Several recently released long grain varieties are more resistant to sheath blight than the older long grain varieties (Table 12). Fungicides are available for reducing sheath blight. Ask a Cooperative Extension Service agent for the latest information on fungicides for sheath blight management.

Sheath Rot

This disease is caused by the fungal pathogen Sarocladium oryzae. Symptoms are most severe on the uppermost leaf sheaths that enclose the young panicle during the boot stage. Lesions are oblong or irregular oval spots with gray or light-brown centers and a dark reddish-brown, diffuse margin (Fig. 74), or the lesions may form an irregular target pattern. On U.S. rice varieties, the lesion is usually expressed as a reddish-brown discoloration of the flag leaf sheath. Early or severe infections affect the panicle so that it only partially emerges. The unemerged portion of the panicle rots, turning florets reddish-brown to dark brown. Grains from damaged panicles are discolored reddish-brown to dark brown and may not fill. A powdery white growth consisting of spores and hyphae of the pathogen may
be observed on the inside of affected sheaths. Insect or mite damage to the boot or leaf sheaths increases the damage from this disease.

This disease affects most rice varieties. The disease is usually minor, affecting scattered tillers in a field. Occasionally, larger areas of a field may have significant damage. Control measures are not recommended. Fungicidal sprays used in a general disease management program reduce damage, but recent studies show that several bacterial pathogens commonly cause similar sheath rot symptoms on rice in Louisiana. Fungicides would have little effect on these pathogens.

**Sheath Spot**

This disease is caused by the fungus *Rhizoctonia oryzae*. The disease resembles sheath blight, but is usually less severe. The lesions produced by *R. oryzae* are found on sheaths midway up the tiller or on leaf blades (Fig. 76). Lesions are oval, 0.5 - 2 cm long and 0.5 - 1 cm wide. The center is pale green, cream or white with a broad, dark reddish-brown margin (Fig. 77). Lesions are separated on the sheath or blade and do not form the large, continuous lesions often found with sheath blight. The pathogen attacks and weakens the culm under the sheath lesion on very susceptible varieties. The weakened culm lodges or breaks over at the point where it was infected. Lodging caused by sheath spot usually occurs midway up the culm.

This disease is usually minor on Louisiana rice. Some fungicides used to manage sheath blight also reduce sheath spot.

**Stackburn**

This disease was first observed on rice growing in Louisiana and Texas. Stackburn or Alternaria leaf spot is caused by the fungal pathogen *Alternaria padwickii*. It is now common on rice around the world. The disease is present in all rice fields in Louisiana. Only occasional spots are observed, but the disease may be more severe in restricted areas of a field. The spots are typically large (0.5 - 1 cm in diameter), oval or circular, with a dark brown margin or ring around the spot (Fig. 75). The center of the spot is initially tan and eventually becomes white or nearly white. Mature spots have small dark or black dots in the center. These are sclerotia of the fungus. Grain or seeds affected by the disease have tan to white spots with a wide, dark brown border. The disease causes discoloration of kernels, or the kernels stop development and grains are shriveled.

This fungus is the most common seedborne fungus in Louisiana and may cause seedling blight. It is more common on panicles and grain than on leaves in Louisiana.

No specific control recommendations are available, but seed-protectant fungicides will help reduce the seedling blight caused by this pathogen and will reduce the number of spores available to cause leaf infections.

**Stem Rot**

Stem rot caused by the fungus *Sclerotium oryzae* is an important disease in Louisiana. Often, losses are not detected until late in the season when it is too late to initiate control practices. Stem rot causes severe lodging, which reduces combine efficiency, increases seed sterility and reduces grain filling.

The first symptoms are irregular black angular lesions on leaf sheaths at or near the water line on plants at tillering or later stages of growth (Fig. 58). At later stages of disease development, the outer sheath may die, and the fungus penetrates to the inner sheaths and culm. These become discolored and have black or dark brown lesions. The dark brown or black streaks have raised areas of dark fungal mycelium on the surface and gray mycelium inside the culm and rotted tissues. At maturity, the softened culm breaks, infected plants lodge and many small, round, black sclerotia develop in the dead tissues (Fig. 59).

The pathogen overwinters as sclerotia in the top 2 - 4 inches of soil and on plant debris. During water-working and establishment of early floods, the
hydrophobic sclerotia float on the surface of the water and often accumulate along the edge of the field and on levees because of wind action.

After a permanent flood is established, the sclerotia float to the surface, contact the plant, germinate and infect the tissues near the waterline. The fungus then penetrates the inner sheaths and culm, often killing the tissues. The fungus continues to develop, forming many sclerotia in the stubble after harvest.

Most commercial varieties of rice are not highly resistant to stem rot. The disease is favored by high nitrogen levels. Early maturing varieties are usually less affected by stem rot. In addition, applications of potassium fertilizer reduce disease severity in soils where potassium is deficient. Stem rot is more serious in fields that have been in rice production for several years.

Suggested management measures include using early maturing varieties, avoiding very susceptible varieties, burning stubble or destroying by cultivation after harvest to destroy sclerotia, using crop rotation when possible, applying potassium fertilizer, avoiding excessive nitrogen rates and using foliar fungicides recommended by the Cooperative Extension Service. Several cultural practices may reduce stem rot. These include fluctuating the water level in the field so stagnant water does not remain at the same level on the lower leaf sheaths, and draining water from the field at the tillering and early jointing stages of growth, while keeping the soil saturated. These practices may lead to the development of leaf blast and other problems, however.

Water-Mold and Seed-Rot

With the extensive use of the water-seeding method of planting rice, it has become more difficult to obtain uniform stands of sufficient density to obtain maximum yields. The most important biological factor contributing to this situation is the water-mold or seed-rot disease caused primarily by fungi in the genera Achlya and Pythium. Recently, certain Fusarium spp. also have been found associated with molded seeds. The disease is caused by a complex of these fungi infecting seeds. The severity of this disease is more pronounced when water temperatures are low or unusually high. Low water temperatures slow the germination and growth of rice seedlings, but do not affect growth of these pathogens. In surveys conducted in Louisiana during the early 1970s and 1980s, an average of 45 percent of water-planted seeds were lost to water-mold.

In addition to the direct cost of the lost seeds and the cost of replanting, water-mold also causes indirect losses caused by the reduced competitiveness of rice with weeds in sparse or irregular stands. Also, replanting or overseeding the field causes the rice to mature late when conditions are less favorable for high yields because of unfavorable weather and high disease pressure.

Water-mold can be observed through clear water as a ball of fungal strands surrounding seeds on the soil surface. After the seeding flood is removed, seeds on the soil surface are typically surrounded by a mass of fungal strands radiating out over the soil surface from the affected seeds (Figs. 68). The result is a circular copper-brown or dark green spot about the size of a dime with a rotted seed in the center. The color is caused by bacteria and green algae which are mixed with the fungal hyphae.

Achlya spp. (Fig. 68) normally attack the endosperm of germinating seeds, destroying the food source for the growing embryo and eventually attacking the embryo. Pythium spp. (Fig. 69) usually attack the developing embryo directly. When the seed is affected by the disease, the endosperm becomes liquified and oozes out as a white, thick liquid when the seed is mashed. The embryo initially turns yellow-brown and finally dark brown. If affected seeds germinate, the seedling shoot and root are attacked and the seedling is stunted. When infection by Pythium spp. takes place after the seedling is established, the plant is stunted, turns yellow and grows poorly. If the
weather is favorable for plant growth, seedlings often outgrow the disease and are not severely damaged.

The disease is less severe when rice is water-seeded when weather conditions favor seedling growth. High and low temperatures averaging above 65 degrees F favor seedling growth, and water-mold is less severe. Seeds should be vigorous and have a high germination percentage. Seed with poor vigor will be damaged by water-mold fungi when water-seeded.

Treat seed with a recommended fungicide at the proper rate to reduce water-molds and seed diseases. A list of recommended fungicides is available through Cooperative Extension Service agents. Most rice seed is treated by the seedsman and is available to the grower already treated. Seed-protectant fungicides differ in their effectiveness. Information on recent results from seed-protectant fungicide trials can be obtained from an extension agent or the Rice Research Station. In field tests, these fungicides have increased stands over those produced by untreated seeds from 25 percent to 100 percent.

**White Tip**

This disease is caused by the nematode *Aphelenchoides besseyi*. Characteristic symptoms which appear after tillering include the yellowing of leaf tips, white areas in portions of the leaf blade (Fig. 86), stunting of affected plants, twisting or distortion of the flag leaf, and distortion and discoloration of panicles and florets. Leaf tips change from green to yellow and eventually white. The tip withers above the white area, becoming brown or tan and tattered or twisted. Resistant varieties may show few symptoms and still have yield loss. The nematode infects the developing grain and is seedborne.

This disease is present endemically in Louisiana, but is considered a minor rice disease. Fumigation of seeds in storage will reduce the nematode population. No other specific control measures are recommended.

**Physiological Disorders**

**Cold Injury**

Cold weather affects rice development most at the seedling or reproductive stages of growth. Seedling damage is expressed as a general yellowing of the plants or as yellow or white bands across the leaves where a combination of wind and low temperature damaged the plants at the soil line (Fig. 84). Cold weather (less than 60 degrees F) present during the reproductive stages causes panicle blanking or blighting. Individual florets or the whole panicle may be white when emerging. To eliminate this problem, adjust planting date to avoid low temperatures.

**Panicle Blight**

The cause of panicle blight is unknown. It can be severe on certain varieties of rice. The disease is characterized by brown or straw-colored discoloration of florets on a panicle branch (Fig. 82). Lesions are not apparent below the grain, thus panicle branches remain green. The grain stops developing and the florets turn gray. It is more severe in late planted rice where the rice is maturing and late night temperatures are high.

**Salinity**

Soil alkalinity, or salinity, and water salinity injure rice and are characterized by areas of stunted, chlorotic plants in the field (Fig. 85). Under severe conditions, leaves turn from yellow to white, and plants die. Affected areas usually have dead or dying plants in the center or on high spots, with stunted yellow or white plants surrounding that area and green, less affected, plants in lower areas. Salt deposits may be seen on the edges of leaves, on clods of soil and other high areas of the field. Damage is reduced by flushing with water low in salt.

**Straightthead**

This physiological disorder is associated with sandy soils, fields with arsenic residues or fields having large amounts of plant residue incorporated into
the soil before flooding. Panicles are upright at maturity because the grain does not fill or panicles do not emerge from the flag leaf sheath. Hulls (palea and lemma) may be distorted and discolored, with portions missing or reduced in size.

Distorted florets with a hook on the end are called “parrot beak” (Fig. 83) and are typical of straighthead. Plants are darker green or blue-green and often produce new shoots and adventitious roots from the lower nodes. These symptoms can be mimicked by herbicide damage. Manage by using resistant varieties (Table 12) and draining at the first internode elongating stage of growth to dry the soil until it cracks. Do not plant susceptible varieties under conditions favorable for straighthead development, which include very sandy soils, soils with high levels of undecomposed plant residue or fields with a history of arsenical herbicide (such as MSMA) applications.

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| Medium grain                                      |       |               |                   |                |           |              |
| Bengal     | S      | MS            | MS                | MR              | MS        | VS           |
| Lafitte    | MR     | MS            | MS                | R               | MS        | VS           |
| Mars       | S      | MS            | MS                | MR              | MS        | VS           |
| Rico-1     | S      | MS            | S                 | MS              | MS        | MR           |
| Saturn     | MR     | MS-S          | MS                | S               | S         | S            |

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, and VS = very susceptible. Varieties labeled S or VS for a given disease or disorder may be severely damaged under conditions favoring disease development.
Table 13. Scouting and management practices recommended for major rice diseases.

**BLAST**

**Scouting or Determining Need**
Varieties with low levels of resistance should be scouted for leaf blast during the vegetative stages of growth. Leaf blast is more likely when the flood is lost, excessive nitrogen is used or rice is planted late in the growing season. Sandy soils and tracts near tree lines are probable areas where blast will occur. There are no predictive systems to foresee when rotten neck blast will occur. Since significant damage is already done when the disease is first detected, preventive sprays are required on susceptible varieties, especially when blast has been detected in the region.

**Management Practices**
Plant varieties resistant to blast. Avoid late planting. Plant as early as possible within your recommended planting period. For leaf blast, reflood if field has been drained. Maintain flood at 4 - 6 inches. Do not overfertilize with nitrogen. Apply a fungicide if necessary. Contact your county agent for the latest information on available fungicides and timing.

**SHEATH BLIGHT**

**Scouting or Determining Need**
Rice following rice or soybeans is more likely to be affected. Dense stands and excessive nitrogen favor disease development. Scout varieties from mid-tillering until heading. The field should be sampled at several locations to determine the percentage of tillers infected. Spraying a fungicide is warranted if 5 percent to 10 percent or 10 percent to 15 percent of the tillers are infected on susceptible or moderately susceptible varieties, respectively.

**Management Practices**
Avoid dense stands and excessive nitrogen fertilizer. Most long grain varieties have little resistance to sheath blight. Medium grain varieties are more resistant. Timing and rate of fungicide applications are critical for good sheath blight management. Check with your county agent for the latest information on fungicides. Fallow periods, with disk or control grasses in the field (which serve as sources of inoculum) and break down crop residue, help reduce disease pressure.

**BROWN SPOT**

**Scouting or Determining Need**
Disease is most severe when plants are nitrogen deficient or under other stresses. Plants become more susceptible as they approach maturity.

**Management Practices**
Maintain good growing conditions through proper fertilizer, land leveling, good soil preparation and other cultural practices. Use recommended seed protectant fungicides to reduce inoculum. Correct stress conditions in the field. All varieties are susceptible, but some more than others.

**NARROW BROWN LEAF SPOT**

**Scouting or Determining Need**
Disease is most severe from panicle emergence to maturity. Several pathogenic races are present, and new races develop to affect resistant varieties.
Management Practices
Many commercial varieties have acceptable levels of resistance to this disease. Check with your Cooperative Extension Service agent for latest information on the use of available fungicides. Apply fungicides at recommended rate and timing.

STEM ROT
Scouting or Determining Need
Most commercial varieties are susceptible. Infection takes place at the waterline, and angular black lesions form. The number of infected tillers may reach 100 percent in areas of the field where debris and sclerotia from the previous crop have collected after being windblown on the water surface.

Management Practices
Applying potassium will reduce disease severity where potassium is deficient. Early maturing varieties are less affected by stem rot. Destroying the sclerotia in stubble by crop rotation, tillage or burning can reduce disease pressure.

WATERMOLD AND SEED-ROT
Scouting or Determining Need
The fungi causing this disease are soil- and waterborne. They occur in most rice fields. The seed-rot and water mold disease is most severe under flooded conditions when the water is cold.

Management Practices
Seed should be treated with recommended fungicides. Check with your county agent for recent information on effective seed-protectant fungicides. Draining the seeding flood and flushing as needed help prevent watermold. Seeding should not begin until the mean daily temperature reaches 65 degrees F.

SEEDLING BLIGHT
Scouting or Determining Need
The fungi causing this disease can be seedborne or soilborne. They are common and are normally present on seeds or in soil. Seedling blight is common in drillseeded or dry broadcast rice.

Management Practices
Treating seed with seed-protectant fungicides effectively reduces seedling blight. Check with your extension agent for recent information on effective seed-protectant fungicides.

GRAIN SPOTTING AND PECKY RICE
Scouting and Determining Need
Since these diseases are normally associated with insect damage, scout for the rice stink bug. Monitor fields from immediately after pollination until kernels begin to harden. Sample with a sweep net and count the number of insects collected. If the number of stink bugs exceeds 30 per 100 sweeps during the first two weeks after heading, treat the field with a labeled insecticide. During the dough stages, fields should be treated when 100 or more stink bugs are collected per 100 sweeps.

Management Practices
Control of the stink bugs with insecticides is the only management measure for grain spotting and pecky rice.
**Insect Management**

Dennis R. Ring, James Barbour, William C. Rice, Michael Stout and Mark Muegge

Insects can be a major factor limiting rice production in Louisiana. The rice water weevil and the rice stink bug are key pests. They cause significant reduction in the quantity and quality of rice produced each year in Louisiana. Other insects attacking rice, though not key pests, can occasionally reduce rice yield and quality significantly. These include the rice seed midge, rice leaf miner, fall armyworm, chinch bug, rice stalk borer and sugarcane borer.

This section contains information about the identification, life cycle, injury to rice and current scouting and management practices for these pests. The scouting and management recommendations are based on the best available information and will be modified as additional research is conducted. Current treatment recommendations are summarized in Table 14, but consult your county agent and the most recent “Insect Control Guide” (Louisiana Cooperative Extension Service publication 1838) to get the latest recommendations for specific insect pests.

**Rice Seed Midge, Chironomus spp.**

Description and life cycle

Adult midges can be seen in swarms over rice fields, levees, roadside ditches and other bodies of water. Adult midges resemble small mosquitoes but lack the needle-like mouthparts and hold their forelegs up when resting. Eggs are elongate and laid in strings, usually on the surface of open water. The strings are held together by a sticky material that forms a gelatinous coat around the eggs. After emerging, the larvae move to the soil surface, where they live in spaghetti-like tubes constructed from secreted silk, plant debris and algae (Fig. 89). The larvae go through four instars before pupating under water in the tubes. The life cycle from egg to adult requires 10-15 days.

**Injury**

Midge larvae injure rice by feeding on the embryo of germinating seeds and on the developing root and shoot of young rice seedlings. Most economic injury to rice is the result of stand loss caused by larvae feeding on the embryo of germinating seeds. Reports of injury caused by rice seed midge have increased in recent years.

**Scouting and Management**

Rice seed midge is a problem only for rice seeds and seedlings in water-seeded fields. Midges are not a problem in rice more than 2 to 4 inches tall. Scout fields for midges and midge injury within five to seven days after seeding. Repeat scouting at five- to seven-day intervals until rice seedlings are about 3 inches tall. Midge
presence is indicated by larval tubes on the soil surface (Fig. 89). There are many midge species, most of which do not attack rice, and the presence of midge tubes alone does not indicate the need to treat a given field.

Midge injury is indicated by the presence of chewing marks on the seed, roots and shoots and by the presence of hollow seeds (Fig. 90). If midge injury is present, and plant stand has been reduced to fewer than 15 plants per square foot, treatment may be necessary. The only available method for control of rice seed midge is to drain fields to reduce numbers of midge larvae. Re-seeding of heavily infested fields may be necessary. The potential for damaging levels of seed midge can be reduced or prevented by using recommended water and crop management practices. Holding water in rice fields for more than two to three days before seeding encourages the buildup of large midge numbers before seeding and should be avoided. Practices that encourage rapid seed germination and seedling growth, such as using pre-sprouted seed and avoiding planting in cool weather, will help to speed rice through the vulnerable stage and reduce the chances for serious damage.

**Chinch bug, Blissus leucopterus leucopterus (Say)**

**Description and life cycle**

Chinch bugs overwinter as adults in grass clumps, leaf litter and other protected areas, emerging in early- to mid-spring to feed and mate on grass hosts including small grains such as wheat, rye, oats and barley. Adults are small, black insects about 1/6-inch long, with white front wings (Fig. 91). Each wing has a triangular black spot near the outer wing margin. Adults lay white, elongate eggs 1/24-inch long behind the lower leaf sheaths or in the soil near the roots. Eggs turn red as they mature and larvae emerge in seven to 10 days. There are five nymphal instars. Early instar nymphs are red with a yellow band on the front part of the abdomen. Last instar nymphs are black and gray with a conspicuous white spot on the back (Fig. 91). The life cycle from egg to adult takes 30-40 days, and adults may live two to three weeks.

**Injury**

Chinch bugs are a sporadic pest of rice in Louisiana. Economic injury to rice generally occurs when favorable weather conditions and production practices allow chinch bugs to build up in corn, sorghum and wheat fields. As these crops mature and are harvested, large numbers of chinch bugs may move to young plants in nearby rice fields. Serious economic losses have resulted from chinch bug infestations in north Louisiana. The trend toward increasing acreage of small grains increases the potential for chinch bug problems.

Chinch bug injury results when adults and nymphs feed on the leaves and stems of rice plants. Feeding on young seedlings causes leaves and stems to turn light brown. High numbers of chinch bugs can kill young plants, severely reducing plant stands.

**Scouting and Management**

Check unflooded rice near small grain fields every three to five days from seedling emergence until application of permanent flood. Check foliage in rice fields for chinch bugs. Thresholds for chinch bugs in rice are not available. If high numbers of chinch bugs are present and plant stands are being reduced, the field should be treated. Cultural and chemical control methods are available. Cultural control consists of flooding infested fields to kill chinch bugs or to force them to move onto rice foliage where they can be treated with an insecticide. This tactic requires that levees be in place and that rice plants be sufficiently large to withstand a flood. Cultural control may be more expensive than chemical control. Contact your county agent for specific recommendations if chemical control is needed.

**The Fall Armyworm, Spodoptera frugiperda (J. E. Smith)**

**Description and Life Cycle**

The fall armyworm feeds on most grasses found in and around rice fields. It is also a serious pest of corn and pasture...
grasses. Since rice is not its preferred host, the fall armyworm is only an occasional pest on rice. Adult moths are about 1 inch long with gray-brown sculptured front wings and whitish hind wings. The front wings of male moths have a white bar near the wing tip. This bar is absent in female moths. Females lay masses of 50 to several hundred whitish eggs on the leaves of rice and other grasses in and around rice fields. Egg masses are covered with moth scales and appear fuzzy.

The larvae emerge in two to 10 days, depending on temperature, and begin feeding on rice plants. They vary from light green to brown to black, but have distinctive white stripes along the side and back of the body. Larvae feed for two to three weeks, developing through four instars. Mature larvae are about 1 inch long and have a distinctive inverted “Y” on the head. Mature larvae prepare a cocoon and pupate in soil or decomposing plant material. Moths emerge in 10 to 15 days, mate and disperse widely before laying eggs on new plants. At least four generations per year occur in Louisiana.

Injury
Fall armyworm larvae feed on the leaves of young rice plants, destroying large amounts of tissue. Leaf loss of 25 percent in the seedling stage can reduce rice yields by about 130 pounds per acre. When large numbers of armyworms are present, seedlings can be pruned to the ground, resulting in severe stand loss. Fall armyworm infestations generally occur along field borders, levees and in high areas of fields where larvae escape drowning. The most injurious infestations occur in fields of seedling rice that are too young to flood. Larvae from the first overwintering generation, occurring in early spring, are the most injurious. Infestations later in the season may cause feeding injury to rice panicles, although this is rare.

Scouting and Management
After germination of seedlings, scout fields weekly for larvae on plants. Sample plants every 10 feet along a line across the field, and repeat this process in a second and third area of the field. Treat when there is an average of one armyworm per two plants.

Fall armyworm management consists of cultural, chemical and biological control. Parasitic wasps and pathogenic microorganisms frequently reduce armyworm numbers below economical levels. Since adults lay eggs on grasses in and around rice fields, larval infestations can be reduced by effective management of grasses. When fall armyworm numbers reach threshold levels, cultural or chemical control is needed. Cultural control consists of flooding infested fields for a few hours to kill fall armyworm larvae. This requires that levees be in place and that rice plants be large enough to withstand a flood. Cultural control may be more expensive than chemical control. Contact your county agent for specific recommendations if chemical control is needed.

The Rice Leaf Miner, Hydrelia griseola (Fallen)
Description and Life Cycle
Adults are dark flies with clear wings and a metallic blue-green to gray thorax. Less than 1/4 inch long, they can be seen flying close to the water and lighting on rice leaves. White eggs are laid singly on rice leaves that float on the water. Transparent or cream-colored legless larvae emerge in three to six days and begin feeding between the layers of the rice leaf. Larvae become yellow to light green as they feed. Mature larvae are about 1/4 inch long (Fig. 92). The larvae feed for five to 12 days before pupating. Adults emerge after five to nine days and live two to four months. Under ideal conditions the life cycle can be completed in as little as 15 days. In cool weather the life cycle can extend for more than one month.

Injury
The rice leaf miner is a sporadic problem in Louisiana. Problems are more severe in continuously flooded rice than in periodically flooded rice, and when water is more than 6 inches deep. Injury is usually greatest on the upper side of levees where water is deepest. The rice
leaf miner attacks rice during the early spring. Injury is caused by larvae feeding between the layers of the rice leaf (Fig. 93). Leaves closest to the water are attacked and killed. As larvae move up the plant, additional leaves die. When leaf miner numbers are high, entire plants can die, reducing stands severely (Fig. 94). In Louisiana, rice leaf miner seems to attack fields in the same vicinity year after year.

Scouting and Management

Scout fields for rice leaf miners by walking through flooded rice fields and gently drawing the leaves of rice plants between the thumb and forefinger. Bumps in the leaves indicate the presence of leaf miner larvae or pupae. If leaf miners are present and plant numbers are reduced to less than 15 per square foot, treatment is necessary. Rice leaf miner management involves cultural control or insecticide application, perhaps both. Maintaining water depth at 4-6 inches will usually prevent problems with rice leaf miner. If leaf miners are present, lowering the water level in rice fields so that rice leaves can stand up out of the water also will help to prevent injury. Contact your county agent for specific control recommendations.

Rice Water Weevil, Lissorhoptrus oryzophilus Kuschel

Description and Life Cycle

The rice water weevil is the most injurious insect pest in Louisiana rice production. Yield losses of more than 1,000 pounds per acre can occur from severe infestations. The total annual loss in Louisiana attributed to this pest is between $9 million and $10 million.

Rice water weevil adults are grayish-brown beetles about 1/8 inch long with a dark brown V-shaped area on their backs (Fig. 95). Rice water weevils overwinter as adults in grass clumps and ground debris near rice fields. Wing muscles of overwintering adults degenerate so these insects cannot fly. When spring temperatures rise to 65 degrees F, wing muscles begin to regenerate and adults begin moving out of overwintering sites. Adults fly in the early evening, with little flight occurring when night-time temperature falls below 60 degrees F.

Adults will invade either unflooded or flooded rice fields and begin feeding on the leaves of rice plants. The flight muscles degenerate again as the weevils become established, and the adults cannot fly. Females begin egg laying in flooded fields or in areas of unflooded fields that contain water, such as low spots, potholes or tractor tire tracks. Females deposit white, elongate eggs in the leaf sheath at or below the waterline. White, legless, C-shaped larvae with small brown head capsules emerge from the eggs in about seven days.

First instar larvae are about 1/32 inch long and feed in the leaf sheath for a short time before exiting the stem and falling through the water to the soil, where they burrow into the mud and begin feeding on the roots of rice plants (Fig. 96). The larvae continue to feed in or on the roots of rice plants developing through four instars in about 27 days. Larvae increase in size with each succeeding molt. Fourth instar larvae are about 3/16 inch long. Larvae pupate in oval, watertight cocoons attached to the roots of rice plants. The cocoons are covered with a compacted layer of mud and resemble small mud balls (Fig. 97).

Adults emerge from the cocoons in five to seven days, are able to fly a short time after emerging and may attack rice in the same or a different field. The life cycle from egg to adult takes about 35 days. The length of the life cycle is temperature-dependent, however, and can vary from 25 to 45 days in warm and cool weather, respectively. The number of generations per year vary with latitude. Two and a partial third generation occur in the southern rice-growing areas of Louisiana. One and a partial second generation occur in the northern rice-growing areas. Most adult weevils emerging in late July to early August (first or second generation weevils in north or south Louisiana, respectively) fly to overwintering sites and remain inactive until the next spring.
Injury

Adult rice water weevils feed on the upper surface of rice leaves, leaving narrow longitudinal scars that parallel the midrib (Fig. 98). Adult feeding injury can kill plants when large numbers of weevils attack very young rice, but this is rare and is usually localized along the field borders. Most economic injury is caused by larvae feeding on or in rice roots. This feeding or root pruning reduces root surface area, resulting in decreased nutrient uptake by the plant. Plants with severely pruned root systems (Fig. 99) turn yellow and appear to be nitrogen deficient. At harvest, plants from heavily infested fields will be shorter than normal and have lower yields. Each larva found in a 4-inch (diameter) by 3-inch (deep) core sample reduces rice yield by 40 pounds per acre.

Scouting and Management

Management practices for the rice water weevil are changing. Furadan is expected to be available on a limited basis to producers in the 1999 growing season. At the time of writing, the only other compound which has received a label for use is Karate.

Numbers of larvae on rice roots peak 21-35 days after flooding. At this time most of the larvae will be large, and a significant amount of root pruning will have occurred. Early scouting of fields can indicate if and when treatment is required to prevent damaging infestations resulting in reduced insecticide costs and higher yields.

Take the first larval count seven to 14 days after establishment of the permanent flood in a drill-seeded system or 10 to 14 days after plants have emerged from the water in a water-seeded system. At least six sites should be randomly selected in each field. At each site, remove a single core of plants and soil 4 inches in diameter and 3 inches deep and place it in a 10-quart bucket with a 40-mesh screen bottom (Fig. 100). Wash the soil from the plant roots through the screen bottom in the bucket by thoroughly stirring the soil in the water. Push the bucket up and down vigorously in the water several times. This forces water up through the screen bottom and helps to separate larvae from any plant debris remaining in the bucket. After a few seconds, larvae will float to the surface where they can be counted and removed. Repeat the washing procedure several times to make sure all larvae in a sample have been counted. If you don’t find larvae in any sample, sample the field again in five to seven days. If the average number of larvae per sample is fewer than five, sample the field again three to five days later. If the average number of larvae per sample is five or more, the field should be treated. Sampling should cease when the field has been treated or when plants have reached the 2 mm panicle stage of development.

Timing of Karate is crucial, and more than one application may be required. One day after permanent flood has been established, begin scouting for adults. Examine plants in a one square foot area in five to 10 locations per field for presence of adults. Continue scouting every three to four days until treatment is needed. Treat when there is one adult weevil per square foot. Check at least 10 locations before making a decision. Scout and treat as needed until green ring, when plants are no longer susceptible. Do NOT make more than five applications at the 3.84 fluid ounce per acre rate. Do NOT apply within 21 days of harvest.

Karate kills adult weevils, but not eggs and larvae. Egg laying (oviposition) must be prevented. Once eggs are laid in rice stems or larvae are in the roots, Karate is not effective. Applying Karate for eggs or larvae is a waste of money in addition to the loss caused by weevils. Sampling plans and economic injury levels for the rice water weevil are being developed. Recommendations for the management of the rice water weevil with foliar insecticides may change.

Management of the Rice Water Weevil using Cultural Control

Fields may be drained to reduce rice water weevil numbers. Draining fields is the only rice water weevil control method available for rice grown in rotation with
Draining fields for rice water weevil control requires careful planning so conflicts with weed, disease and fertilizer management programs can be avoided or minimized. Contact your county agent for specific information on variety and management practices for cultural control or for specific chemical control recommendations.

**The Stem Borers: The Rice Stalk Borer, Chilo plejedellus (Zink)**

The Sugarcane Borer, Diatra saccharalis (F)

**Description and Life Cycle, The Rice Stalk Borer**

The rice stalk borer is a sporadic pest of rice in Louisiana. Rice stalk borers overwinter as last instar larvae in the stalks of rice and other host plants. Larvae pupate in the spring, and adult moths emerge in early to late June, mate and live on various hosts until rice stem diameter is large enough to support tunneling larvae. Adults are about 1 inch long with pale white fore and hind wings tinged on the edges with metallic gold scales. Front wings are peppered with small black dots (Fig. 101). Although egg laying may begin in late May, injurious infestations usually occur from August through September. Flat, oval cream-colored eggs are laid in clusters of 20 to 30 on the upper and lower leaf surfaces. Eggs are laid at night over one to six days. Larvae emerge in four to nine days, crawl down the leaf toward the plant stem. Larvae may feed for a short time on the inside of the leaf sheath before boring into the stem. They are pale yellow-white with two pairs of stripes running the entire length of the body (Fig. 102). These stripes distinguish rice stalk borer larvae from sugarcane borer larvae, which have no stripes. Mature larvae are about 1 inch long. Larvae move up and down the stem feeding for 24 to 30 days before moving to the first joint above the waterline, chewing an exit hole in the stem and constructing a silken web in which to pupate. Pupae are about 1 inch long, brown and smoothly tapered. There are two to three generations per year in rice.

**Injury**

Injury to rice results from stalk and sugarcane borer larvae feeding on plant tissue as they tunnel inside the stem. Injury is often first noticed when the youngest partially unfurled leaf of the plant begins to wither and die, resulting in a condition called deadheart (Fig 104).
Later in the growing season, these rice stems are weakened and may lodge before harvest. Stem feeding that occurs during panicle development causes partial or complete sterility and results in the white-head condition (Fig. 105). The white, empty panicles are light in weight and stand upright.

**Scouting and Management**

Unfortunately by the time signs of field infestations (deadhearts, white-heads) are noted, it is usually too late to apply effective chemical treatments. For chemical treatments to be effective, you must time application to coincide with larval emergence so small larvae are killed before they enter rice stalks. Once larvae enter the stalks, pesticides are not effective. Extensive scouting of rice fields is required to time pesticide applications properly. Scouting can be conducted for stem borer adults or egg masses. Eggs are laid over an extended period, however, and although some injury may be prevented, satisfactory control using chemical treatments is difficult and has not been generally successful. No pesticides are labeled specifically for stem borer control in rice. Stem borer eggs and larvae are parasitized by the wasps, *Trichogramma minutum* Riley and *Agathis stigmaterus* (Cresson), respectively. It is believed these parasites play an important role in maintaining stem borer numbers below economic levels.

**Rice Stink Bug, Oebalus pugnax (E)**

**Description and Life Cycle**

Adult rice stink bugs are shield-shaped, metallic-brown insects about ½ inch long (Fig. 106). Rice stink bugs overwinter as adults in grass clumps and ground cover. They emerge from overwintering sites in early spring and feed on grasses near rice fields before invading fields of maturing rice. Adults live 30-40 days. Females lay masses of light-green cylindrical eggs on the leaves, stems and panicles of rice plants. Eggs are laid in parallel rows with about 20-30 eggs per mass. As they mature, eggs become black with a red tint. Immature stink bugs (nymphs) emerge from eggs in four to five days in warm weather or as long as 11 days in cool weather. Nymphs develop through five instars in 15-28 days. Newly emerged nymphs are about 1/16 inch long, with a black head and antennae and a red abdomen with two black bars (Fig. 107). Nymphs increase in size with successive molts and the color of later instars becomes tan-green. There are four generations per year in Louisiana, two on weed hosts and two on rice. Only one generation develops in a given field, however.

**Injury**

Rice stink bugs feed on the rice florets and developing rice kernels. Feeding on florets reduces rough rice yields, but most economic loss results from stink bugs feeding on developing kernels. Kernel feeding results in discolored or “pecky” rice kernels that have lower grade and poor milling quality (Fig. 108). Both adult and nymph rice stink bugs feed on developing rice grains, but adults alone account for most economic losses in rice. Relationships between stink bugs and stink bug injury developed in Texas show a strong increase in percentage of pecky rice and a strong decrease in percentage of head yield with increasing numbers of adult stink bugs during the heading period. When numbers of immature stink bugs were included, this relationship did not change.

**Scouting and Management**

Several natural enemies are important in reducing rice stink bug numbers in rice. Adults and nymphs are parasitized by the flies, *Beskia aelops* (Walker) and *Euthera tentatrix* Lav. Rice stink bug eggs are parasitized by the tiny wasps, *Oencyrtus anasae* (Ashm.) and *Telonomus podisi* (Ashm.). Management relies significantly on the activity of these naturally occurring biological control agents. Insecticidal control based on the results of field scouting is recommended when rice stink bugs escape from the control provided by natural enemies.
Rice fields should be sampled for stink bugs using a 15 inch diameter insect sweep net once each week beginning immediately after pollination and continuing until kernels harden. Do not sample fields at midday when stink bugs may be seeking shelter from the heat in the shade at or near the ground. Avoid sampling field borders, where stink bug numbers are often higher than in the field interiors, also. A sample consists of 10 consecutive 180 degree sweeps made while walking through the field. Hold the net so that the lower half of the opening is drawn through the foliage. After 10 successive sweeps, count the number of rice stink bug nymphs and adults. Normally 10 samples of 10 sweeps each are made per field. Alternatively, 100 random sweeps may be taken per field. During the first two weeks of heading, fields averaging one or more rice stink bugs per three sweeps (30 or more per 100 sweeps) should be treated with an insecticide. After the first two weeks of heading, treat fields when an average one or more stink bugs per sweep (100 or more per 100 sweeps) is found. Do not treat fields within two weeks of harvest. Contact your county agent for specific treatment recommendations.

Other Insect Pests of Rice

Several other insects may occasionally attack rice in Louisiana. They include the southern green stink bug, Nezara viridula (L.), several grasshopper species and the larvae of several species of skippers (Figs. 109, 110) and tiger moths. The numbers of these insects in rice fields are usually below levels justifying treatment, but they may increase rapidly under favorable conditions and yield losses can occur. Contact your county agent for specific treatment recommendations.
### Table 14. Rice insect control recommendations.

<table>
<thead>
<tr>
<th>Insect</th>
<th>Treatment</th>
<th>Dosage Per Acre</th>
<th>Active Ingredient</th>
<th>Limitations</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armyworms(^1)</td>
<td>Methyl Parathion</td>
<td>1/2 lb. ec</td>
<td>15 days</td>
<td></td>
<td>Treat when there is one armyworm per two plants.</td>
</tr>
<tr>
<td></td>
<td>Malathion(^2)</td>
<td>1.5 lb ec</td>
<td>15 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.t.(^2,3)</td>
<td>0.5 lb</td>
<td>0 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinch Bugs(^3)</td>
<td>Methyl Parathion</td>
<td>3/4 lb. ec</td>
<td>15 days</td>
<td>Flood fields first.</td>
<td></td>
</tr>
<tr>
<td>Rice Leaf Miners</td>
<td>Methyl Parathion</td>
<td>1/4 lb. ec</td>
<td>5 days</td>
<td></td>
<td>Treat when stands are reduced to less than 15 plants per square foot.</td>
</tr>
<tr>
<td>Rice Stink Bug</td>
<td>Malathion</td>
<td>1/2 lb. ec</td>
<td>7 days</td>
<td></td>
<td>Treat when there are 30 stink bugs per 100 sweeps during the first two weeks of heading.</td>
</tr>
<tr>
<td></td>
<td>Sevin</td>
<td>1 to 1 1/4 lb. WP</td>
<td>15 days</td>
<td></td>
<td>Treat when there are 100 stink bugs per 100 sweeps from two weeks after heading begins until two weeks before harvest.</td>
</tr>
<tr>
<td></td>
<td>Methyl Parathion</td>
<td>1/4 lb. ec</td>
<td>15 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Penncap M</td>
<td>1/4 lb. ec</td>
<td>15 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Malathion(^2)</td>
<td>0.5 lb</td>
<td>15 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice Water Weevil(^5)</td>
<td>Furadan(^4,5)</td>
<td>1/2 lb. (15 to 20 lbs. of 3% sand core granules)</td>
<td>14 days</td>
<td>Treat when 40% of the plants have feeding scars on the newest unfurled leaf, and/or when there is an average of 5 rice water weevil larvae per core.</td>
<td></td>
</tr>
<tr>
<td>Rice Seed Midge</td>
<td>Drain fields</td>
<td></td>
<td></td>
<td></td>
<td>Treat when stands are reduced to less than 15 plants per square foot.</td>
</tr>
</tbody>
</table>

1 Flooding is effective for armyworm control if plants are sufficiently developed. Do not use Methyl Parathion within 14 days of applying propanil.
2 For rice grown in rotation with crawfish.
3 There are several formulations available. Follow label directions.
4 Apply from one day before to four days after permanent flood for dark rice field mosquito control.
5 Do not apply propanil after applying furadan. Do not apply to fields used for crawfish production. Do not apply more than once per season.
6 Consult your county agent for specific water management procedures.

WARNING: Re-entry times for workers entering treated fields should be strictly observed. Be sure to check the label for this information.
Blackbirds (Icterinae), are among the most numerous birds in rice-growing areas. The red-winged blackbird (Agelaius phoeniceus) is the most abundant breeding bird in the rice-growing area of southwestern Louisiana. Red-winged blackbirds are responsible for most rice depredation. Brown-headed cowbirds (Molothrus ater), common grackles (Quiscalus quiscula) and boat-tailed grackles (Quiscalus major) cause the rest of rice damage. Blackbirds are responsible for significant economic loss during sprouting and ripening stages each year. Damage to sprouting rice can be particularly severe in water-seeded rice. Most damage occurs in southwestern Louisiana where rice is seeded before resident flocks of blackbirds have dispersed to breed and before the departure of all wintering migrants. As many as 50 winter roost sites in Louisiana may be used by more than 125 million blackbirds annually. Economic losses caused by blackbird damage are most severe in fields located within five miles of winter roost sites. These areas are traditionally adjacent to coastal marshes.

Both federal and state governments recognize that blackbirds are important depredators of agricultural commodities. Blackbirds are migratory birds and are provided protection under provisions of the Migratory Bird Treaty Act. They may be controlled without a federal permit when found depredating agriculture crops, however. Louisiana considers blackbirds pests that may be taken any time by any legal means.

No conventional agricultural pesticides are labeled for use in reducing blackbird damage in rice production. No lethal chemical compound that will control blackbirds in agricultural crops safely and effectively is likely to be registered for general use by producers in the near future. Methods of control involve alternative cultural practices, scare devices, chemical repellents and restricted use toxicants.

Cultural Practices
1. Drill seed rice on a well-prepared seedbed. Water-plant only where a continuous uniform flood of 2 to 6 inches can be kept on the rice.
2. Delay planting rice in high blackbird infested areas (such as coastal areas) until after April 1. Arrange planting programs so fields near roost areas or coastal marshes are planted last. Begin planting nearest the farm headquarters and progress to more sensitive areas later in the season.
3. Block planting in areas of traditionally severe bird damage, such as in fields adjacent to coastal marshes, can be effective in reducing damage on individual farms. This method requires that a group of farmers in a given area plant all or most of their rice on, or near, the same date.
4. Consider alternate crops in high bird pressure areas where there has been a history of extreme damage to rice crops.
5. Habitat modification and clean cropping may be helpful in reducing the number of resident blackbirds damaging rice crops at maturity. Removing brush and trees from ditch banks, levees, fence rows and keeping fields free of weeds will eliminate blackbird habitat in and around field areas.

Scare Devices
1. Propane exploders with timers to turn them off and on automatically each day are the most effective scare devices used to move feeding blackbirds from freshly planted rice fields and after maturity. There should be a least one exploder for every 25 acres of crop to be protected. They should be elevated on a barrel, stand or truck bed to “shoot” over the crop. They should be moved around the field every few days. Ex-
ploders should be reinforced with live ammunition fired from shotgun and .22 caliber rifles. In addition, pyrotechnics such as 12-gage shell crackers, rope fire crackers and rocket bombs can be helpful when used with live ammunition and propane exploders.

2. Aircraft can be used to harass birds in newly planted fields, but this method is costly under most situations.

Chemical Repellents

1. Chemical repellents are compounds which must be registered by EPA. When placed on rice seed or other bait, repellents will deter consumption of newly planted seed by blackbirds. They work by causing olfactory, gustatory or digestive irritation in the target animal. At present, no chemical repellents are registered to protect newly planted rice seed.

2. Methyl anthranilate is a chemical compound that holds promise for protecting seed rice. Testing is under way.

Restricted Use Toxicants

1. Avitrol (4-aminopyridine) is a poison with flock-alarming properties used to control blackbirds and starlings in, on or around the area of feedlots, structures, nesting, roosting and feeding sites. It acts in such a way that only a part of the flock feeding on the bait will ingest treated bait, react and frighten the rest away. Birds that react and alarm a flock usually die. Avitrol is for sale to and use only by certified applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators Certification. Distribution of Avitrol should be limited to scattered spot placements that will provide feeding opportunities only for the necessary number of target birds. After the birds’ feeding pattern has been established through prebaiting, untreated bait is removed and dilute treated bait applied only at sites where the target birds are actively feeding. Do not apply this product where nontarget bird species are feeding. Treated bait should be picked up and removed from the field each day.

2. Compound DRC-1339 is an avicide registered for use in parts of southwestern Louisiana under a 24 (C), local-needs label. It can be used only by personnel of the USDA Animal Damage Control Program and those working under their supervision. DRC-1339 is applied to brown rice baits broadcast on blackbird staging areas near winter and spring roosting sites. Depending on the number of birds killed, the product is sometimes effective in reducing rice depredations associated with large concentrations of roosting blackbirds. DRC-1339 has not been effective when used in areas where blackbirds are widely dispersed.

Harvest and Storage

Harvesting Rice

William A. Hadden

Harvest Considerations

Proper adjustment of harvesting equipment is essential for reducing harvest loss and monitoring optimum harvest efficiency, but preharvest losses and management losses can both result in poor harvest efficiency. Preharvest losses are caused by factors such as adverse weather, bird depredation or damage caused by certain insects and disease. Management losses are caused by premature draining and improper harvest moisture.

Combine losses can be minimized with proper harvester adjustment. Losses generally occur at the header (gathering unit loss), at the cylinder or during separation. Gathering loss includes shattering, loose stalk and lodged stalk loss. Shatter loss occurs when loose grains or panicles fail to enter the header. Loose stalk losses occur when panicles are cut
but do not enter the header. Lodged stalk
loss occurs when panicles are broken over
or separated from the plant before cutting.
Cylinder loss includes those grains of
rice which are left on the heads and are
carried out the rear of the combine.
Separation loss is that portion of threshed
grain carried out of the combine with the
straw residue.

Rice harvest losses may be determined
by counting the number of grains per
square foot found to have been missed by
the combine. A count of 33 to 42 grains
per square foot (depending on the variety)
equals 100 per acre.

Rice losses can be reduced by taking
certain measures. The moisture status of
the crop needs to be determined before
harvest. In general, most rice should be
harvested when grain moisture ranges
from 18 percent to 22 percent.

The combine should be operated at
proper forward speed, platform height and
reel speed. Cut as high as possible but
with enough straw to ensure efficient
threshing. Proper reel adjustment will
prevent shattering and provide a uniform
feed into the header.

The proper cylinder speed maintains
good threshing while preventing cracking
and hulling of the rice. Excessive cylinder
speeds at lower moisture will increase
kernel breakage. If the cylinder speed is
too slow, some of the grain will not be
removed, especially at higher moisture.

Separation losses can be decreased by
maintaining proper setting at the chaffer
and sieves. Adjust air flow to remove as
much trash as possible without losing grain
from the rear of the combine.

Combine Capacity

A combine typically operates 50
percent to 80 percent of the time it is in
the field. This is known as its field
efficiency. Harvesting speed usually
ranges from one to four miles per hour.
The capacity of the combine can be
determined with this formula:

\[
C = S \times W \times \text{Field Efficiency}
\]

Where:
\( C \) = Capacity in acres per hour
\( S \) = Speed, MPH
\( W \) = Width, feet
Field Efficiency = 50 to 80 percent

Example:
\[
C = 2 \times 20 \times 60 = 2.9 \text{ acres/hour}
\]

Where: \( S = 2, W = 20 \), Field Efficiency = 60

Rice Drying and Storage
Douglas L. Deason

The rice grain on a plant, and even on
a single panicle, may vary considerably in
moisture content as the plant nears
readiness for harvest. This is because of
grain location on the plant and because of
the time interval over which a plant
blooms. When a sample is cut to
determine moisture content, an average
moisture is determined; some grains are
wetter and some drier than this average
moisture. Harvesting at 18 percent to 22
percent wet basis moisture content gives
the best milling yields. Most varieties
harvested at 23 percent and above tend to
have too many chalky immature kernels. If
rice is allowed to field-dry to moistures
less than 16 percent, the driest kernels are
subjected to wetting and drying cycles
caused by air drying potential changes
from day to night. This causes stress cracks
(checks) in some of the kernels, reducing
milling yields. This reduction of milling
yield as the rice dries is more severe in
some varieties than others. Rapid
rewetting by rain, once rice reaches 15
percent or less moisture content, is a key
cause of lower head rice yields. To obtain
the highest milling yields, some method of
artificially drying rice from harvest
moisture to a safe storage level of 12
percent to 13 percent is necessary.

For a drying system to produce a high
milling, quality rice, the system must (1)
operate so the rice is not overdried and (2)
provide a controlled drying rate adequate
to reduce rice from 22 percent to 16 percent or below in no more than seven days. If drying rates are slower than this, damage from molds and fungi will discolor the milled kernels. This is called heat damage or stackburn. At 16 percent moisture or less, the rice does not provide a favorable environment for mold and fungi growth, and moisture content can be safely reduced at a slower rate. A moisture content of not more than 13 percent in any portion of the bin is recommended for safe storage. Rice mills prefer 12 percent to 12.5 percent moisture for best milling results.

Certain precautions should be taken before placing the season's first rice in bins for drying. The bins and plenum area should be cleaned thoroughly, allowed to dry and treated for insects. Air leaks around the base of bins and doors should be caulked and rodent-proofed. Every effort should be made to place clean rice in the drying bins. This includes careful adjustment and supervision of the harvesting equipment and providing for additional cleaning at the bin location if necessary. Excessive foreign material in the grain samples will cause uneven drying in the bins and increase the moisture content of the rice. If levees have more weeds than the fields, levee rice should be harvested and dried separately.

**Drying, Storage and Equipment**

The corrugated metal bin with full perforated metal floors, tightly constructed to protect the rice from weather, insects and rodents, is the centerpiece of rice drying on farms in Louisiana. Other necessary items include drying fans and heaters, combination humidistat-thermostat control, adequate grain handling equipment, plenum temperature thermometers and ample roof ventilators. Optional equipment includes grain stirring devices, grain spreaders and grain temperature monitoring equipment.

Modern rice drying bin systems should be equipped with centrifugal fans although some older farm bins with axial-flow fans adequately dry rice in shallow rice depths. In general axial-flow fans will work satisfactorily for drying up to a depth of 8 feet if sized to deliver 2 ½ to 3 cfm (cubic feet of air per minute) per bushel of rice. For use in bins where depths are more than 8 feet, or in bins equipped with stirrers and drying depths to 16 or 17 feet, the centrifugal fan is an absolute necessity.

**Drying Rice Without Stirrers**

This method of drying rice would be described as drying a static bed of rice with supplemental heat as necessary to keep drying air at a desired humidity level. A minimum air flow rate of 9 cubic feet per minute per barrel (9 cfm/bbl) or 2.5 cubic feet per minute per bushel (2.5 cfm/bu) is necessary to accomplish drying without stackburn. A larger cfm/bu airflow rate will dry more rapidly. For most bin-fan combinations as installed, you can get 2.5 cfm/bu with 7 to 9 feet of rice (a half-bin). Centrifugal fans can be selected to supply 2.5 cfm/bu at depths of more than 9 feet. The use of stirrers would not be necessary, but design depth should be limited by a static pressure requirement of not more than 5.5 inches. In principle this drying method uses a humidistat to turn on heat when the plenum air is above 65 percent relative humidity. Generally, only a slight increase in temperature is necessary to reduce humidity below the humidistat cut-off point. Under normal operation of this system, burners will not add heat when the air humidity is less than 65 percent. The amount of heat added with this method is small, making this the most energy-efficient system. With this system supplying 2.5 to 3 cfm/bu, clean rice at 22 percent moisture should dry to 14 percent moisture in six to seven days.

In this static bed method of drying rice, drying moves from the bottom of the bin upward, with the top layers drying last. Sample the top of the rice regularly as drying progresses, and stop adding heat when the top 12 to 15 inches of rice are at 15 percent moisture.

This static bed system of using a humidistat to control supplemental heat has several shortcomings. Often the rice will not dry evenly throughout the half-
bin; the bottom will be drier than the top, and rice in the center of the bin will have higher moisture content than grain near walls. Transfer of the half-bin of 14 percent rice to another bin mixes the rice. This second bin can be filled with 14 percent rice for completing drying to 12.5 percent. For best milling yield, complete the drying and cooling without adding heat. This can be done by running the fans during the daylight hours when the air humidity is less than 65 percent.

Another shortcoming of this system is that it is rather slow because only one-half bin is dried at a time and small temperature increases are used. Fast harvest and large acreage will require numerous bins or other methods of drying.

A third drawback is that good results depend on a properly operating humidistat to control the addition of heat to the drying air. Check the humidistat for proper operation each year and service or replace as necessary. The work of the fan will lower the relative humidity of outside air about 5 percent. Turn heat on when outside air humidity is 70 percent or above to obtain 65 percent or less relative humidity under the grain. If the humidistat is not operating properly, excessive heat may be added, the bottom layers of the bin will be overdried and milling yields will be reduced.

When using the thermostat in combination with the humidistat, set the thermostat at 95 degrees F. Used in this manner, the humidistat should control the burners to add heat, and the thermostat should serve as a safety device to turn heat off above 95 degrees F. Efforts to dry deep layers of 8 to 9 feet of rice with only a thermostat for controlling heat will generally give poor results if a stirring device is not used.

In recent years, several manufacturers have offered low temperature rise, modulating valve controlled heaters. These units can provide precise temperature control of air under the drying floor. This type of controller is more energy efficient than the older on-off controls. Drying deep layers of rice (8 to 9 feet) with this temperature controlled system will probably provide faster drying when compared to a humidistat controlled system. Using this temperature control system in Louisiana, with a 90 degree F control point, relative humidity will be reduced to 50 percent to 55 percent. Producers have reported excellent milling quality on rice dried with this equipment.

**Drying Rice With Stirring Equipment**

Stirring equipment for moving rice from bottom of bin to top has some important advantages for rice producers. (1) It reduces the risk of uneven drying from overdrying of lower layers caused by poorly constructed and managed humidistats. Rice directly in the bin’s center is not stirred and generally remains at a higher moisture level than rice in other areas. This must be carefully monitored. (2) It reduces the problem of hot spots and uneven drying caused by trash separation in the bin. Vertical screws do a good job of evenly distributing foreign material and leveling the top surface. (3) It allows the addition of a larger amount of heat and provides more drying capacity with the same bin and fan equipment; most systems with stirrers can dry at least twice as much rice in a given period as can static bed - humidistat controlled drying. (4) It requires only a thermostat.

The stirring device should be turned on and started when 2 feet of rice cover the floor evenly. The stirrers should be operated constantly throughout the drying period and until rice is dry enough to cease adding heat to the air. Initial thermostat setting should be 90 degrees F until depth of rice is equal to one-fourth of total drying fill. For example, if 16 feet of rice will be dried, the thermostat should be set to 90 degrees F for up to 4 feet of depth; from 4 to 8 feet, the thermostat should be set to 95 degrees F. Increase the thermostat setting gradually to a maximum of 105 degrees F at maximum fill of 16 to 17 feet. Airflow should be a minimum of 1.25 cfm/bushel or 4.5 cfm/barrel at maximum stirred drying depth. A 15 HP centrifugal fan is required for a 27 feet diameter bin, 20 HP for 30 feet diameter
and 30 HP for 36 feet diameter bin. Two 20 HP fans may provide a more even air and heat distribution with the 36 feet diameter bin than will one 30 HP fan. With 16 to 17 feet of rice and this airflow, the fans will operate against a static pressure of about 6 inches of water.

Properly managed stirrer equipped bins increase drying capacity, reduce drying risk and result in more uniform milling.

**Other Rice Drying Methods**

Large farm operations may have harvest and drying rates that necessitate consideration of methods other than the two research-proven methods discussed. One alternative to increasing drying capacity of a farm bin drying system is to use a continuous flow dryer to remove no more than 3 percent or 4 percent of moisture initially. A continuous flow dryer needs a large holding capacity, a low heated air temperature and good mixing action within the dryer. Rice grain temperatures coming from the dryer should not exceed 95 degrees F. Rice coming from a continuous flow dryer at about 17 percent to 18 percent moisture should be transferred to a stirred bin to complete the drying operation. Beginning with rice at a 22 percent moisture, this system must be managed carefully to prevent significant milling yield losses. Using a continuous flow dryer to remove 4 percent to 5 percent moisture from rice initially at 19 percent to 20 percent moisture will probably cause significant milling yield losses. No research has shown this to be possible without costly reduction of whole grain and total milling yield.

Another type of drying system now being marketed in rice-growing areas is a high airflow in-bin continuous flow concept. This system consists of a bin with a perforated floor and one or two fans designed to provide five to 10 cfm/bu of airflow to as much as a 10-feet drying depth of grain. Unloading augers are installed on the floor of the bin and are controlled to operate so that a layer of grain is removed from the bottom of bin as it becomes sufficiently dry. This system is energy-efficient relative to energy required per pound of water removed. This type of continuous flow system also provides a relatively large volume of wet grain storage ahead of the dryer.

The dryers should be operated at 4 to 6 feet of rice depth with an intended air flow of about 10 cfm/bu of rice. The rice leaving the dryer should not have a grain temperature of more than 100 degrees F to 105 degrees F. Base decisions on this exit grain temperature on milling yield of the rice samples. The grain from this dryer (16 percent to 17 percent rice) is placed in nearly full bins at reduced risk to complete drying. Do not expect this continuous bin dryer to remove 4 or more percent of moisture from rice with initial moisture of 20 percent or less without milling yield loss. Most desirable operation of this continuous flow bin drying system requires a level grain surface across the full bin width and uniform air temperatures under the bin. Both requirements are difficult to achieve.

**Management of Stored Rice**

After rice has been dried and cooled to a moisture of 12 percent to 13 percent, sample it for temperature and moisture content during storage. Sample several times in the first couple of weeks after completion of drying because percentage of grain moisture often increases because of moisture migrating to the kernel surfaces. Aeration is required when this occurs. Once grain moisture stabilizes, check moisture and temperature no less than once a month, preferably every two weeks. High temperature spots indicate locations with excess moisture and require aeration.

As winter approaches, aeration can be used to lower the temperature of the grain mass. This will reduce temperature differences in the bin which cause moisture migration in the grain mass. High moisture grain is most likely to occur in the top center portion of the bin and along the walls. For aeration cooling purposes, operate fans when outside air temperature is 10 degrees F or more below grain temperature. In Louisiana, relative
humidity of the air blown during aeration must be considered. Extended aeration at high air flows and low humidities can cause severe overdrying of the bottom rice layers in the bin. Preferred relative humidity for aeration is in the 60 percent to 70 percent range. Do not operate fans during fog or rain.

Rice Economics

For many decades rice has been among the top cash crops produced in Louisiana. Rice production supports an infrastructure of storage, processing, transportation and agricultural supply industries larger than that of many other agricultural commodities produced in the state.

Other major rice-producing states are Arkansas, California, Mississippi, Missouri and Texas, which, together with Louisiana, accounted for an average of about 1.4 percent of world rice production from 1986 - 1997. During the same period, about 35 percent of this production was exported, accounting for about 19 percent of total world trade in rice. More than 97 percent of the world’s rice was domestically consumed in the country where produced during this period.

Farm Management

A key to successful farm management is understanding and estimating enterprise production costs. This is particularly true for rice growers because rice is relatively expensive to produce compared to other field crops typically grown in Louisiana. Several production decisions which must be made during the growing season based on the current status of the rice crop may impact costs significantly. Examples of these include insecticides, fungicides and fertilizer. All these decisions are partially a function of environmental conditions that have prevailed since planting and subsequent effects on the yield potential of a particular field of rice. Unfortunately, these effects cannot be accurately predicted on a yearly basis, so their impacts on production costs are among the most difficult to estimate before they occur.

A systematic method for estimating production costs is an enterprise budget. An enterprise budget is simply an itemized list of projected expenditures and returns associated with a given crop production system. The budget includes the total input requirements for that enterprise based on the sequence of operations. Its purpose is to summarize enterprise cost and return projections for use in management decisions. Much of the information needed to construct an enterprise budget is available from historical farm records and current projections of input costs and output prices. Two illustrations of enterprise budgets for rice are provided in Tables 15 and 16.

In Table 15, the budget is typical of a water-planted owner-operator situation in southwestern Louisiana. Owner-operators can compare their cost estimates with the budget in Table 15 using the “Your Farm” column. Similarly, tenant-operators can compare their situations with the projected budget presented in Table 16. In analyzing crop enterprise budgets, it is extremely important to evaluate the levels of profitability associated with various levels of product price and yield projections.

Not all items in these tables are direct cash outlays. Interest on operating capital and certain items included in the fixed expenses section of the budgets are not always direct cash costs. Noncash expense items are used to approximate the economic cost associated with devoting capital and machinery resources to the rice enterprise. An interest charge on operating capital indicates that money tied up in the current year’s rice crop could be used elsewhere. Items such as depreciation (economic, not tax, depreciation), insurance and housing (for equipment) are typically included under the fixed expenses category. These cost items must be covered if the farm business is to be profitable in the long run.
Using the cash expense information in the enterprise budget, a farmer can develop a whole-farm cash flow analysis for the business. Cash flow analysis summarizes the sources and uses of cash in the business and requires estimating total expenditures and receipts which occur during specified periods of the year (usually quarters). Cash flow deficits in a given quarter indicate the need for cost control measures or possible borrowing. The best source of data for developing a cash flow statement is historical farm records. (Monthly bank statements can provide much of the needed information.)

An important, yet often neglected, aspect of farm management is the control phase. Just as it is important to project expenditures and receipts for the upcoming season, it is important to compare actual events and outcomes with earlier projections. Deviations in the actual outcome from the initial projection can be analyzed and become the basis for next year's plan of action. This type of continual monitoring of the business allows the farmer to control his or her operation better and to detect potential problems.

Marketing

Contrasted to that of other high energy foods, rice consumption in the United States has been increasing for many years, especially since the early 1980s. In fiscal 1993 it reached nearly 20 pounds of milled rice per capita, which does not include more than four pounds per capita used in brewing. Projections for fiscal 1996 indicate expected consumption per capita to increase to more than 21 pounds and four pounds respectively for food and brewers’ use. Of the milled rice consumed domestically, about 80 percent to 85 percent is used directly for food and processed food, and 15 percent to 20 percent for brewing. On a rough rice basis, forecasted total domestic per capita use now amounts to more than 35 pounds per year (Table 17).

From fiscal years 1988 to 1995, U.S. rice exports were distributed as follows: Mid-East, 39.51 percent; North America, 18.26 percent; Caribbean Islands, 7.17 percent; Africa, 9.73 percent; Asia, 7.39 percent; Europe, 11.83 percent; and South America, 6.11 percent. These percentages are somewhat skewed because of large purchases by Japan in 1993. Other relatively large exporting countries are Thailand, Pakistan, Burma, Italy and, at times, China, Japan and Taiwan. Aggregated world rice production and trade data are in Table 18.

Because of the relatively large number of buyers and public auctions operating in Louisiana, and the state’s proximity to both domestic markets and export facilities, Louisiana growers have perhaps a wider range of marketing choices than growers in other rice-producing states. Louisiana ranks second to Arkansas in number of operating rice mills.

Historically the South’s largest producer of medium grain rice, Louisiana was edged out by Arkansas in 1995 in production of medium grain. From 1992 to 94, medium grain acreage has fluctuated from 30 percent to 40 percent of total rice acreage in Louisiana, but fell to 23 percent in 1995 and 13 percent in 1996.

Long grain rice generally commands a higher price than medium grain rice of the same grade (Table 19). Anticipating premiums the market will pay for long grain rice is one of the most important, but more difficult, marketing tasks many Louisiana growers face.

Anticipating probable market prices for either class has also become more difficult since 1972. Further development of futures trading for rice holds some promise in this regard as well as to create a large number of marketing alternatives not previously available. In any case, a grower must choose when to sell, and the choice will likely affect income significantly in any given year. There is often no way to predict prices with any degree of certainty, and the choice of when to sell is often dictated by financial circumstances of individual growers.

Figure 111 (p. 105) shows the products derived from milling 100 pounds of long
grain rough rice. The exact proportions of each of the products produced depend on a number of management and environmental factors.

Rice is exported mainly in 100-pound and 50-kilo bags in the form of either raw or parboiled milled rice, but significant amounts also move to the export market in bulk form as rough and brown rice, and in consumer packages.

**U.S. Farm Policy for Rice**

In general, the historical objectives of government farm policy have been to 1) ensure a secure and wholesome food supply, 2) to maintain a viable agricultural industry and 3) to support the income of farmers. Government intervention into the domestic agricultural industry began with the Agricultural Adjustment Act of 1933, and rice was designated as one of the Act's original seven commodities. Succeeding Acts have all had significant influence on the rice industry, resulting in a 92 percent to 95 percent participation rate of rice farmers in the rice program nationwide.

Government programs for rice in the first half of the 1990s were governed by the Farm Bill of 1990. This bill resulted from two statutes, The Food, Agriculture, Conservation and Trade Act of 1990 and The Agricultural Reconciliation Act of 1990. Goals of the 1990 Farm Bill were to: 1) further reduce the federal deficit by reducing payment acres, 2) help maintain farm income growth through increased planting flexibility and expanding exports through market-oriented loan rates and 3) enhance environmental quality through the Conservation Reserve Program and the Water Quality Protection Program.

Important provisions of the 1990 Farm Bill (as compared to the 1985 bill) applicable to rice were: 1) freezing of minimum target prices for five years at $10.71/cwt, 2) maintaining the current method of loan rate calculation, 3) maintaining the current method of deficiency payment rate calculations for 1991-93 crop years, with subsequent changes for the 1994-95 crop years, 4) changing triggers for acreage reduction programs (ARP) and 5) introducing normal and optional flexibility acres (NFA and OFA). Provisions continued under the 1990 Act included: voluntary compliance, marketing loans, nonrecourse loans based on a loan rate, deficiency payments based on a target price, crop acreage base, acreage reduction program, flexibility acres and payment limitations.

With the passage of the new farm bill, the Federal Agriculture Improvement and Reform Act of 1996, the role of the federal government in price support activities for agricultural commodities, including rice, will change dramatically. The new program basically consists of a seven-year transition period, during which time government support payments for agricultural commodities will be reduced annually and producer returns from production of these commodities will depend more and more on market prices.

A summary of the rice provisions of the new farm bill is in Table 16. The new farm program eliminates the rice target price/deficiency payment price support system which has been in effect for many years. Eligible producers would enter into a seven-year, production flexibility contract for the 1996-2002 period. Producers would receive guaranteed, direct, fixed payments on 85 percent of eligible rice base acreage. These payments would generally decline over the seven years and would not be tied to market prices. Total annual commodity spending would be set in advance and divided between commodities, based partly on previous payment history. The share of total commodity spending allocated to rice is estimated at 8.47 percent under this new bill, compared to 12 percent to 13 percent paid to rice producers over the previous several years.

Transition payments for rice under the new farm program are projected to range from $2.94 down to $2.03 per hundredweight over the 1996-2002 period. Payments would be based on established rice program yields and paid.
on 85 percent of eligible rice base acreage. These payment rates compare with a maximum deficiency payment rate of $4.21 per hundredweight under the 1985 and 1990 farm bills.

Nonrecourse loans for commodities, including rice, were retained from the previous farm program. The maximum loan rate for rice over the life of the bill was set at the 1995 level of $6.50 per hundredweight. Marketing loan provisions (LDP program) for rice were extended from previous legislation with repayment at world prices or 70 percent of loan, if world market prices are below the loan rate. Producers would be free to plant any program crop, oilseed crop or industrial or experimental crop on their paid rice base acreage and could plant in excess of their base. Planting fruits and vegetables would be prohibited on payment acres. Haying and grazing would be permitted as a flex crop on payment acreage. All acreage reduction (set-aside) programs were eliminated. Current payment limitations were reduced from $50,000 to $40,000 per entity, although the three-entity provisions of the previous farm program were retained. The bill extends provisions limiting marketing loan gains and loan deficiency payments to $75,000 per person per year.

Table 15. Estimated costs and returns per acre. Rice, water planted, owner-operators, Southwest Louisiana, 1998.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Price</th>
<th>Quantity</th>
<th>Amount</th>
<th>Your Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INCOME</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>cwt</td>
<td>10.00</td>
<td>48.0000</td>
<td>480.00</td>
<td></td>
</tr>
<tr>
<td>Rice checkoff</td>
<td>cwt</td>
<td>0.08</td>
<td>-48.0000</td>
<td>-3.84</td>
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</tr>
<tr>
<td><strong>TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>476.16</td>
</tr>
<tr>
<td><strong>DIRECT EXPENSES</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CUSTOM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer Truck</td>
<td>acre</td>
<td>3.50</td>
<td>1.0000</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>Airplane seed</td>
<td>cwt</td>
<td>4.55</td>
<td>1.4000</td>
<td>6.37</td>
<td></td>
</tr>
<tr>
<td>Global Pos. System</td>
<td>acre</td>
<td>0.45</td>
<td>6.3500</td>
<td>2.86</td>
<td></td>
</tr>
<tr>
<td>Airplane Slam</td>
<td>acre</td>
<td>5.15</td>
<td>2.0000</td>
<td>10.30</td>
<td></td>
</tr>
<tr>
<td>Airplane furadan&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>4.00</td>
<td>0.5200</td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>Airplane 2,4-D</td>
<td>acre</td>
<td>5.10</td>
<td>1.0000</td>
<td>5.10</td>
<td></td>
</tr>
<tr>
<td>Airplane Fert</td>
<td>cwt</td>
<td>4.05</td>
<td>1.4000</td>
<td>5.67</td>
<td></td>
</tr>
<tr>
<td>Airplane benlate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>4.50</td>
<td>0.7000</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>Airplane Insect&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>3.95</td>
<td>0.1300</td>
<td>0.51</td>
<td></td>
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<tr>
<td>Drying Rice</td>
<td>cwt</td>
<td>0.95</td>
<td>53.9300</td>
<td>51.23</td>
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<tr>
<td>Storage Rice&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>0.40</td>
<td>48.0000</td>
<td>19.20</td>
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<td><strong>FERTILIZER</strong></td>
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<td></td>
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</tr>
<tr>
<td>Nitrogen</td>
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</tr>
<tr>
<td>Phosphate</td>
<td>lbs</td>
<td>0.26</td>
<td>51.0000</td>
<td>13.26</td>
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</tr>
<tr>
<td>Potash</td>
<td>lbs</td>
<td>0.14</td>
<td>51.0000</td>
<td>7.14</td>
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<td><strong>FUNGICIDES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Quadris&lt;sup&gt;b&lt;/sup&gt;</td>
<td>oz.</td>
<td>2.19</td>
<td>4.2000</td>
<td>9.20</td>
<td></td>
</tr>
<tr>
<td>Benlate 50% WP&lt;sup&gt;b&lt;/sup&gt;</td>
<td>lbs</td>
<td>16.50</td>
<td>0.3500</td>
<td>5.77</td>
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</table>
## HERBICIDES

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<th>Amount</th>
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<tbody>
<tr>
<td>Stam M4</td>
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<td>4.58</td>
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<tr>
<td>2,4-D-LV4</td>
<td>pt</td>
<td>1.78</td>
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<td>1.78</td>
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## HIRED LABOR

<table>
<thead>
<tr>
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<th>Unit</th>
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<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other labor</td>
<td>hour</td>
<td>7.50</td>
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## INSECTICIDES

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<thead>
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<th>Quantity</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Furadan 3G³</td>
<td>lbs</td>
<td>0.80</td>
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<td>7.07</td>
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<tr>
<td>Methyl parathion 4E</td>
<td>pt</td>
<td>3.31</td>
<td>0.1300</td>
<td>0.43</td>
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</tbody>
</table>

## OTHER

<table>
<thead>
<tr>
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<th>Quantity</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>sqft</td>
<td>0.08</td>
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<td>1.08</td>
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## SEED

<table>
<thead>
<tr>
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<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice seed</td>
<td>lbs</td>
<td>0.21</td>
<td>140.0000</td>
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## OPERATOR LABOR

<table>
<thead>
<tr>
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<th>Unit</th>
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<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractors</td>
<td>hour</td>
<td>7.50</td>
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</tr>
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<td>Self-Propelled Eq.</td>
<td>hour</td>
<td>7.50</td>
<td>0.3800</td>
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## IRRIGATION LABOR

<table>
<thead>
<tr>
<th>Item</th>
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<th>Price</th>
<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrig sys 9 fl WP</td>
<td>hour</td>
<td>7.50</td>
<td>0.3150</td>
<td>2.36</td>
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</table>

## OWNER LABOR

<table>
<thead>
<tr>
<th>Item</th>
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<th>Quantity</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Self-Propelled Eq.</td>
<td>hour</td>
<td>12.00</td>
<td>0.4180</td>
<td>5.02</td>
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## DIESEL FUEL

<table>
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<tr>
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<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractors</td>
<td>gal</td>
<td>0.74</td>
<td>9.4218</td>
<td>6.97</td>
</tr>
<tr>
<td>Self-Propelled Eq.</td>
<td>gal</td>
<td>0.74</td>
<td>2.6980</td>
<td>2.00</td>
</tr>
<tr>
<td>Irrig sys 9 fl WP</td>
<td>gal</td>
<td>0.74</td>
<td>77.9450</td>
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## GASOLINE

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</thead>
<tbody>
<tr>
<td>Self-Propelled Eq.</td>
<td>gal</td>
<td>1.17</td>
<td>1.9000</td>
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## REPAIR & MAINTENANCE

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<tr>
<th>Item</th>
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<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implements</td>
<td>acre</td>
<td>3.04</td>
<td>1.0000</td>
<td>3.04</td>
</tr>
<tr>
<td>Tractors</td>
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<tr>
<td>Irrig sys 9 fl WP</td>
<td>acre</td>
<td>0.16</td>
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<td>INTEREST ON O.P. CAP.</td>
<td>acre</td>
<td>11.23</td>
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<td>11.23</td>
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</table>

## TOTAL DIRECT EXPENSES

379.43

## RETURNS ABOVE DIRECT EXPENSES

96.73

## FIXED EXPENSES

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Price</th>
<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.0000</td>
<td>5.37</td>
</tr>
<tr>
<td>Tractors</td>
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<td>12.72</td>
<td>1.0000</td>
<td>12.72</td>
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<tr>
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<tr>
<td>Irrig sys 9 fl WP</td>
<td>acre</td>
<td>32.07</td>
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</tr>
</tbody>
</table>

## TOTAL FIXED EXPENSES

77.55

## TOTAL SPECIFIED EXPENSES

456.98

## RETURNS ABOVE TOTAL SPECIFIED EXPENSES

19.18

## ALLOCATED COST ITEMS

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Price</th>
<th>Quantity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead (owner)</td>
<td>acre</td>
<td>64.31</td>
<td>1.0000</td>
<td>64.31</td>
</tr>
</tbody>
</table>
L&W, SWWP
Conv. Rice
acre  29.00  1.0000  29.00
RESIDUAL RETURNS
-74.13

a/ Includes estimated market income only.
b/ Prorated use based on survey results of percentage of rice acreage actually treated in 1991 and expert opinion of these percentages in more recent years.
c/ Drying cost charged on green weight.
d/ This charge represents net income to a land/water lord based on budgets applicable to a tenant version of the above budget, incorporating relevant cost share items, and may be interpreted as an opportunity cost to an owner/operator. It does not represent an estimated cost of land.


<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Price</th>
<th>Quantity</th>
<th>Amount</th>
<th>Your Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dollars</td>
</tr>
<tr>
<td>INCOME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dollars</td>
</tr>
<tr>
<td>Rice</td>
<td>cwt</td>
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<tr>
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<td>10.00</td>
<td>-9.6000</td>
<td>-96.00</td>
<td>285.70</td>
</tr>
<tr>
<td>Water share rent</td>
<td>cwt</td>
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<td>-9.6000</td>
<td>-96.00</td>
<td>285.70</td>
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<td>Rice checkoff</td>
<td>cwt</td>
<td>0.08</td>
<td>-28.8000</td>
<td>-2.30</td>
<td>285.70</td>
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<tr>
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<tr>
<td>DIRECT EXPENSES</td>
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</tr>
<tr>
<td>CUSTOM</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Fertilizer Truck</td>
<td>acre</td>
<td>3.50</td>
<td>1.0000</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>Airplane seed</td>
<td>cwt</td>
<td>4.55</td>
<td>1.4000</td>
<td>6.37</td>
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</tr>
<tr>
<td>Global Pos. System</td>
<td>acre</td>
<td>0.45</td>
<td>6.3500</td>
<td>2.86</td>
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<tr>
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<td>acre</td>
<td>5.15</td>
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<td>10.30</td>
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<tr>
<td>Airplane furadan&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>4.00</td>
<td>0.5200</td>
<td>2.08</td>
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<tr>
<td>Airplane 2,4-D</td>
<td>acre</td>
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<td>1.0000</td>
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<tr>
<td>Airplane Fert</td>
<td>cwt</td>
<td>4.05</td>
<td>1.4000</td>
<td>5.67</td>
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<td>Airplane benlate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>4.50</td>
<td>0.7000</td>
<td>3.15</td>
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<tr>
<td>Airplane Insect&lt;sup&gt;b&lt;/sup&gt;</td>
<td>acre</td>
<td>3.95</td>
<td>0.1300</td>
<td>0.51</td>
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<tr>
<td>Drying Rice&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>28.8000</td>
<td>11.52</td>
<td></td>
</tr>
<tr>
<td>FERTILIZER</td>
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<td></td>
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<td></td>
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<tr>
<td>Nitrogen</td>
<td>lbs</td>
<td>0.23</td>
<td>72.0000</td>
<td>16.56</td>
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<tr>
<td>Phosphate</td>
<td>lbs</td>
<td>0.26</td>
<td>30.6000</td>
<td>7.96</td>
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<tr>
<td>Potash</td>
<td>lbs</td>
<td>0.14</td>
<td>30.6000</td>
<td>4.28</td>
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<td>FUNGICIDES</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadris&lt;sup&gt;b&lt;/sup&gt;</td>
<td>oz.</td>
<td>2.19</td>
<td>2.5200</td>
<td>5.52</td>
<td></td>
</tr>
<tr>
<td>Benlate 50% WP&lt;sup&gt;b&lt;/sup&gt;</td>
<td>lbs</td>
<td>16.50</td>
<td>0.2100</td>
<td>3.47</td>
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<td></td>
<td></td>
<td></td>
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<td>Stam M4</td>
<td>qt</td>
<td>4.58</td>
<td>3.6000</td>
<td>16.49</td>
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<tr>
<td>2,4-D-LV4</td>
<td>pt</td>
<td>1.78</td>
<td>0.6000</td>
<td>1.07</td>
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<tr>
<td>Category</td>
<td>Item</td>
<td>Unit</td>
<td>Quantity</td>
<td>Cost</td>
<td>Total</td>
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<td>------------------------</td>
<td>-------------------------</td>
<td>------</td>
<td>--------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>HIRED LABOR</td>
<td>Other labor</td>
<td>hour</td>
<td>7.50</td>
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<td>7.50</td>
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<tr>
<td>INSECTICIDES</td>
<td>Furadan 3G</td>
<td>lbs</td>
<td>0.80</td>
<td>5.3040</td>
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<td></td>
<td>Methyl pt</td>
<td>pt</td>
<td>3.31</td>
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<td></td>
<td>parathion 4E</td>
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<td>OTHER</td>
<td>Plastic</td>
<td>sqft</td>
<td>0.08</td>
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<td>1.08</td>
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<td>SEED</td>
<td>Rice seed</td>
<td>lbs</td>
<td>0.21</td>
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<td>OPERATOR LABOR</td>
<td>Tractors</td>
<td>hour</td>
<td>7.50</td>
<td>1.5934</td>
<td>11.95</td>
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<tr>
<td></td>
<td>Self-Propelled Eq.</td>
<td>hour</td>
<td>7.50</td>
<td>0.3800</td>
<td>2.85</td>
</tr>
<tr>
<td>IRRIGATION LABOR</td>
<td>Irrig. sys. 10 fl WP</td>
<td>hour</td>
<td>7.50</td>
<td>0.3150</td>
<td>2.36</td>
</tr>
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<td>OWNER LABOR</td>
<td>Self-Propelled Eq.</td>
<td>hour</td>
<td>12.00</td>
<td>0.4180</td>
<td>5.02</td>
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<tr>
<td>DIESEL FUEL</td>
<td>Tractors</td>
<td>gal</td>
<td>0.74</td>
<td>9.4218</td>
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<tr>
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<td>Self-Propelled Eq.</td>
<td>gal</td>
<td>0.74</td>
<td>2.6980</td>
<td>2.00</td>
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<tr>
<td>GASOLINE</td>
<td>Self-Propelled Eq.</td>
<td>gal</td>
<td>1.17</td>
<td>1.9000</td>
<td>2.22</td>
</tr>
<tr>
<td>REPAIR &amp; MAINTENANCE</td>
<td>Implements</td>
<td>acre</td>
<td>3.04</td>
<td>1.0000</td>
<td>3.04</td>
</tr>
<tr>
<td></td>
<td>Tractors</td>
<td>acre</td>
<td>8.89</td>
<td>1.0000</td>
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</tr>
<tr>
<td></td>
<td>Self-Propelled Eq.</td>
<td>acre</td>
<td>12.78</td>
<td>1.0000</td>
<td>12.78</td>
</tr>
<tr>
<td></td>
<td>Irrig. sys. 10 fl WP</td>
<td>acre</td>
<td>0.16</td>
<td>35.0000</td>
<td>5.46</td>
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<td>INTEREST ON</td>
<td></td>
<td>acre</td>
<td>7.58</td>
<td>1.0000</td>
<td>7.58</td>
</tr>
<tr>
<td>O.P. CAP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL DIRECT EXPENSES</td>
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<td></td>
<td></td>
<td>250.04</td>
<td></td>
</tr>
<tr>
<td>RETURNS ABOVE DIRECT EXPENSES</td>
<td></td>
<td></td>
<td></td>
<td>35.66</td>
<td></td>
</tr>
<tr>
<td>FIXED EXPENSES</td>
<td>Implements</td>
<td>acre</td>
<td>5.37</td>
<td>1.0000</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>Tractors</td>
<td>acre</td>
<td>12.72</td>
<td>1.0000</td>
<td>12.72</td>
</tr>
<tr>
<td></td>
<td>Self-Propelled Eq.</td>
<td>acre</td>
<td>27.40</td>
<td>1.0000</td>
<td>27.40</td>
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<td>TOTAL FIXED EXPENSES</td>
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<td></td>
<td></td>
<td>45.48</td>
<td></td>
</tr>
<tr>
<td>TOTAL SPECIFIED EXPENSES</td>
<td></td>
<td></td>
<td></td>
<td>295.52</td>
<td></td>
</tr>
<tr>
<td>RETURNS ABOVE TOTAL SPECIFIED EXPENSES</td>
<td></td>
<td></td>
<td></td>
<td>-9.82</td>
<td></td>
</tr>
<tr>
<td>ALLOCATED COST ITEMS</td>
<td>Overhead (tenant)</td>
<td>acre</td>
<td>53.29</td>
<td>1.0000</td>
<td>53.29</td>
</tr>
<tr>
<td>RESIDUAL RETURNS</td>
<td></td>
<td></td>
<td></td>
<td>-63.11</td>
<td></td>
</tr>
</tbody>
</table>

*Assumes a 1/5 crop share for land and a 1/5 crop share for water with landlord and waterlord each paying 1/5 of fertilizer, chemicals, drying and storage costs, and the waterlord paying all irrigation fuel costs.

\(a/\) Includes estimated market income only.

\(b/\) Prorated use based on survey results of percentage of rice acreage actually treated in 1991 and expert opinion of these percentages in recent years.

\(c/\) Drying cost charged on green weight.
Table 17. U.S. Supply and Use of Rice, Selected Years.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>156.1</td>
<td>159.4</td>
<td>179.7</td>
<td>156.1</td>
<td>97.8</td>
<td>174.2</td>
</tr>
<tr>
<td>Supply</td>
<td>187.2</td>
<td>189.3</td>
<td>213.2</td>
<td>202.5</td>
<td>230.9</td>
<td>213.9</td>
</tr>
<tr>
<td>Total Domestic Use</td>
<td>91.6</td>
<td>95.4</td>
<td>96.7</td>
<td>101.5</td>
<td>98.6</td>
<td>104.2</td>
</tr>
<tr>
<td>Food</td>
<td>63.767.1</td>
<td>69.0</td>
<td>71.2</td>
<td>74.0</td>
<td>77.0</td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td>3.6</td>
<td>3.9</td>
<td>3.6</td>
<td>4.2</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Brewers</td>
<td>15.3</td>
<td>15.4</td>
<td>15.1</td>
<td>15.1</td>
<td>15.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Exports</td>
<td>71.0</td>
<td>66.4</td>
<td>77.0</td>
<td>75.2</td>
<td>100.9</td>
<td>86.0</td>
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<tr>
<td>Total Use</td>
<td>162.6</td>
<td>161.8</td>
<td>173.7</td>
<td>76.7</td>
<td>199.5</td>
<td>190.2</td>
</tr>
<tr>
<td>Ending Stocks</td>
<td>24.6</td>
<td>27.5</td>
<td>39.5</td>
<td>25.8</td>
<td>31.4</td>
<td>23.7</td>
</tr>
</tbody>
</table>

| Area Harvested (mil. acres) | 2.82 | 2.88 | 3.18 | 2.92 | 3.35 | 3.12 |
| Yield (cwt./acre) | 55.29 | 57.31 | 57.36 | 55.1 | 59.64 | 56.35 |
| Avg. Market Price ($/cwt.) | 6.68 | 7.58 | 5.89 | 7.98 | 6.78 | 7.00-8.00 |
| Per Capita Consumption Food and Brewers (lbs. - rough equiv.) | 31.92 | 32.18 | 33.18 | 33.66 | 34.41 | 35.26 |

*Source: Rice Outlook and Situation Yearbook and various other USDA publications.*
**Table 18. Selected World Rice Production and Trade Data, 1997/98**

<table>
<thead>
<tr>
<th>Country</th>
<th>Production&lt;sup&gt;a&lt;/sup&gt; (mmt)</th>
<th>Exports&lt;sup&gt;b&lt;/sup&gt; (tmt)</th>
<th>Imports&lt;sup&gt;b&lt;/sup&gt; (tmt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>27.8</td>
<td>——</td>
<td>100</td>
</tr>
<tr>
<td>Burma</td>
<td>16.6</td>
<td>100</td>
<td>——</td>
</tr>
<tr>
<td>China</td>
<td>195.7</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>India</td>
<td>122.3</td>
<td>1750</td>
<td>——</td>
</tr>
<tr>
<td>Indonesia</td>
<td>51.2</td>
<td>0</td>
<td>1500</td>
</tr>
<tr>
<td>Japan</td>
<td>12.4</td>
<td>——</td>
<td>650</td>
</tr>
<tr>
<td>Philippines</td>
<td>11.2</td>
<td>——</td>
<td>1000</td>
</tr>
<tr>
<td>South Korea</td>
<td>7.4</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>Pakistan</td>
<td>6.5</td>
<td>1700</td>
<td>——</td>
</tr>
<tr>
<td>Thailand</td>
<td>21.2</td>
<td>5250</td>
<td>——</td>
</tr>
<tr>
<td>Vietnam</td>
<td>27.3</td>
<td>3500</td>
<td>——</td>
</tr>
<tr>
<td><strong>Selected Asian Country Sub-Totals</strong></td>
<td><strong>499.4</strong></td>
<td><strong>13300</strong></td>
<td><strong>4250</strong></td>
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<tr>
<td>Australia</td>
<td>1.2</td>
<td>650</td>
<td>——</td>
</tr>
<tr>
<td>Brazil</td>
<td>9.6</td>
<td>——</td>
<td>1000</td>
</tr>
<tr>
<td>EC-12</td>
<td>2.5</td>
<td>350</td>
<td>700</td>
</tr>
<tr>
<td>Iran</td>
<td>——</td>
<td>——</td>
<td>1250</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>——</td>
<td>——</td>
<td>700</td>
</tr>
<tr>
<td>Senegal</td>
<td>——</td>
<td>——</td>
<td>500</td>
</tr>
<tr>
<td>South Africa</td>
<td>——</td>
<td>——</td>
<td>500</td>
</tr>
<tr>
<td>All Others</td>
<td>46.5</td>
<td>2106</td>
<td>10306</td>
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<tr>
<td><strong>Total Non-U.S.</strong></td>
<td><strong>559.1</strong></td>
<td><strong>16406</strong></td>
<td><strong>19206</strong></td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td><strong>8.2</strong></td>
<td><strong>2800</strong></td>
<td>——</td>
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<tr>
<td><strong>World Total</strong></td>
<td><strong>567.3</strong></td>
<td><strong>19206</strong></td>
<td><strong>19206</strong></td>
</tr>
</tbody>
</table>

<sup>a</sup> Production on Million Metric Tons, Rough Rice Equivalent  
<sup>b</sup> Imports and Exports on Thousand Metric Tons, Milled Rice Equivalent  

Exports and Imports Projected for Calendar Year 1998.  
** A dashed line indicates this country was not counted independently of other.  
*** Source: Rice Outlook and Situation Yearbook and various other USDA publications.  
**** Totals may not add due to rounding procedures.

**Table 19. Selected U.S. Rice Industry Data, 1993 Through 1997**

<table>
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<tr>
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<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Target Price per cwt. of Rough Rice</td>
<td>10.71</td>
<td>10.71</td>
<td>10.71</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Price Support Loan per cwt. of Rough Rice</td>
<td>6.50</td>
<td>6.50</td>
<td>6.50</td>
<td>6.50</td>
<td>6.50</td>
</tr>
<tr>
<td>U.S. Average Rough Rice Price per cwt. (12 months)</td>
<td>7.98</td>
<td>6.78</td>
<td>9.15</td>
<td>9.90</td>
<td>9.75</td>
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<tr>
<td>Deficiency Payments per cwt of Rough Rice</td>
<td>3.98</td>
<td>3.79</td>
<td>3.22</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
| Loan and Purchase Rates per cwt.  
  Projected Milled Rice as Determined by Official Test:  
  Long Grain Variety Head Rice | 10.75 | 10.72 | 10.69 | 10.77 | 10.69 |
  Medium & Short Grain Variety Head rice | 9.75 | 9.72 | 9.69 | 9.77 | 9.69 |
  Brokens (second heads, screenings and brewers) | 5.37 | 5.36 | 5.35 | 5.35 | 5.35 |

*Source: Rice Situation and Outlook Yearbook and other USDA publications.*
Table 20. Rice Provisions of the Federal Agriculture Improvement and Reform Act of 1996.

**Contract Payments:**
- Eligible producers can enter into seven-year market transition contracts for 1996-2002.
- Guaranteed direct fixed payments not tied to market prices. Target prices and deficiency payments are eliminated.
- Payments received on 85% of eligible base acreage is based on historical program yield.
- Projected rice payments per unit on paid base acreage:
  - 1996 - $2.75/cwt
  - 1997 - $2.71/cwt
  - 1998 - $2.94/cwt
  - 1999 - $2.81/cwt
  - 2000 - $2.58/cwt
  - 2001 - $2.09/cwt
  - 2002 - $2.03/cwt

**Loan Provisions:**
- Establishes a loan rate for rice at $6.50/cwt.
- Extends marketing loan provisions for rice with repayment at a lower rate if world prices are below loan rate.

**Planting Flexibility:**
- No minimum program crop planting requirements.
- Triple base provisions of 1990 farm bill are eliminated.
- Producers are free to plant any program crop or oilseed crop on rice base acreage without restriction.
- Fruits and vegetables planting prohibited on 85% of base eligible for payment. No restrictions on remaining 15% of base.
- Haying and grazing are permitted on payment acreage during the five principal growing months.
- All acreage reduction programs (ARP) eliminated.

**Payment Limitations:**
- Current payment limitation on direct payments reduced from $50,000 to $40,000.
- Extends limit on marketing loan gains and loan deficiency payments at $75,000.
- Extends three-entity provisions.
Glossary

Active ingredient (ai) - Component of a pesticide that has toxic activity against the pest in contrast to the inert or inactive ingredients.
Adventitious - Refers to a structure arising from an unusual place, such as roots growing from stems or leaves.
Amylographic - Spectrographic analysis of starch.
Amylose - Type of starch in rice grain; higher content makes rice cook drier.
Anaerobic - Refers to an organism able to live and grow without air or free oxygen.
Antagonistic - Decreased activity of an organism from the effect of another organism or compound.
Bacterium (pl. bacteria) - A one-celled microscopic organism that lacks chlorophyll and multiplies by fission (splitting apart).
Biological control - Disease control by means of predators, parasites, competitive microorganisms and decomposing plant material, which restrict or reduce the population of the pathogen.
Biotype - Genetic variant of a species.
Boot - Growth stage of rice when the panicle is more than 1 inch long but before emergence (heading).
Brewers - Smallest size of broken milled rice, which is less than one-quarter of the whole kernel.
Broken yield - Pounds of broken grain milled from 100 pounds of rough rice (total milling yield - head milling yield).
Brokens - Milled rice kernels which are smaller than three-fourths of the whole kernel.
Brown rice - Rice with only the hulls removed.
Carbohydrate - A class of organic chemicals composed of carbon, hydrogen and oxygen; in plants, photosynthesis-produced sugars and starch are examples.
Chevrons - Stripe-like pattern consisting of several curved or V-shaped bands.
Chlorophyll - Green pigment associated with photosynthesis.
Chlorosis - Yellowing of normally green tissue caused by the destruction of the chlorophyll or the partial failure of the chlorophyll to develop.
Coalesce - The coming together of two or more lesions to form a large spot or blotch.
Coleoptile - The protective covering of an emerging shoot, is not a true leaf.
Commingled rice - Rice which has been blended with other rice of similar grain type, quality and grade.
Conidiophore - Specialized hypha bearing conidia.
Conidium (pl. conidia) - A spore formed asexually, usually at the top or side of a specialized hypha (conidiophore).
Crown - Junction between stem and root.
Culm - The jointed stem of grass.
Damage - Economic loss to a crop caused by an insect.
Debris - The crop residues left from the previous crop.
Denitrification - Conversion of nitrate nitrogen to gaseous nitrogen.
Dough - The stage when the endosperm of the grain has begun to solidify.
Drift - The spread of airborne spray droplets to adjacent, non-target areas.
Drying - Removal of kernel moisture to obtain a safe storage condition (about 12.5 percent moisture). Drying is achieved by forcing heated air through grain mass.
Economic injury level - The lowest pest density that will cause damage equal to the cost of control.
Economic threshold - The density of a pest at which control action must be taken to prevent a pest from reaching the economic injury level.
Embryo - The microscopically small plant under the lemma near the point of attachment of the rice seed to the panicle.

Endemic - The normal presence of a pest in a crop year after year in less than epidemic amounts.

Endosperm - Primarily carbohydrate in the form of starch comprising most of the rice seed and used during germination and early plant growth.

Enzyme - Protein specialized to catalyze chemical reactions related to metabolic activity necessary for growth.

EPA - Environmental Protection Agency, an agency of the U.S. government.

Epiphytotic or epidemic - The extensive development of a disease in a geographical area.

Fissuring - The cracking or breaking of grains prior to harvest caused by alternating periods of wetting and drying.

Flag leaf - The uppermost leaf of the rice plant, immediately below the panicle.

Floret - The rice flower including the lemma, palea and reproductive floral parts.

Flush - Flooding of the field with drainage soon after for the purpose of keeping the seed bed moist.

Foliar - Dealing with the foliage of a plant.

Fungus (pl. fungi) - An undifferentiated plant lacking chlorophyll and conductive tissues.

Gelatinization temperature - Index to classify the cooking types of long, medium and short grain.

Gibberellic acid (GA) - Plant growth hormone which stimulates elongation.

Green rice - Rough rice from which the excess moisture has not been removed (usually 18.5 percent to 22.5 percent moisture).

Green ring - Rice plant growth stage during which the tissue of the first internode appears green because of the accumulation of chlorophyll, indicates a change from vegetative to reproductive growth.

GPA - Gallons per acre.

Heading - The period during which panicles exert from the flag leaf sheath.

Head rice - Milled rice kernels which are more than three-fourths of the whole kernel.

Head milling yield - Pounds of head rice milled from 100 pounds of rough rice.

Horizontal resistance - A uniform resistance against all races of a pathogen. The level of resistance is usually only moderate and often influenced by temperature.

Hulling - A process of removing husks from rough rice.

Hulls - Outer husk of the rice grain, usually a waste product, but can be used in rice millfeed and as a filler for feed products.

Hydophobic - Resistant to wetting.

Hypha (pl. hyphae) - A single thread or filament of a fungus.

Imbibed - Absorption of water.

Infestation level - Percent of the population affected by a pathogen, or density of a pest in a unit area.

Inflorescence - A flower cluster.

Injury - Feeding by an insect on a crop but not necessarily causing economic loss.

Instant rice - Milled rice which is cooked, cooled and dried under controlled conditions and packaged in a dehydrated form. Before packaging, it is enriched with thiamine, riboflavin, niacin and iron.

Instar - The stage of an insect between molts.

Internode - The tissue of a rice stem between two nodes (joints).

Internode elongation - Jointing, the rapid lengthening of the tissue between nodes of a rice stem.

IPM - Integrated pest management; the reduction of plant pests through the combined use of various control practices.
Joint - A node.
Key pest - A pest that causes economic loss in most years.
Label - Document accompanying a pesticide container giving specific information about a pesticide, also a legal document specifying how and when a product can be used.
Larva - The second stage of insects with complete metamorphosis (egg, larva, pupa, adult). Larvae look different from adults, live in different places and feed on different food.
Lemma - The larger of two enclosing structures which form the hard outer covering of a rice seed.
Lesion - A localized area of diseased tissue of a host plant.
Lodging - The leaning or falling over of rice plants before harvest.
Long-grain rice - Rice that is long and slender, measuring one-quarter of an inch or more in length. Kernel size is 6.5 mm or more long, and the length-width ratio is from 3.27 to 3.41:1.
Main shoot - The first noticeable above-ground portion of a rice plant originating directly from the seed.
Medium-grain rice - Rice that is plump, measuring less than one-quarter of an inch long. Kernel size is from 5.37 to 6.06 mm and has a length-width ratio of from 2.09 to 2.49:1.
Mesocotyl - Portion of the shoot between the seed and the cotyledon.
Metamorphosis - A change in form during development.
Milk - The stage when the endosperm of the grain is the consistency of milk.
Milled rice - Rice grain from which husks, bran and germ have been removed.
Milling - Processing the rough rice into milled or brown rice.
Mycelium (pl. mycelia) - A mass of fungus hyphae; the vegetative body of a fungus.
Neck - Region of the head consisting of the joint below the panicle.
Necrotic - dead.
Nematode - Generally microscopic, unsegmented roundworm, usually threadlike, free-living or a parasite of plants or animals.
Node - The pronounced area of a rice stem from which a leaf originates.
Nymph - The immature stage of insects with incomplete metamorphosis (egg, nymph, adult). Nymphs look similar to adults, live in the same place as adults and feed on the same food.
Occasional pest - A pest that occasionally causes economic loss.
Overwinter - A term used to describe an insect's ability to survive the winter. The overwintering stage and site are important.
Palea - The smaller of two enclosing structures which form the hard outer covering of a rice seed.
Panicle - The main axis (which is branched) of an inflorescence.
Panicle 2mm - Same as panicle differentiation.
Panicle differentiation (PD) - Rice plant growth stage during which the panicle is recognizable as a small tuft of fuzz about 2 mm (1/8 inch) long.
Panicle initiation (PI) - Rice plant growth stage during which a specialized group of cells in the growing point begin to actively divide. It often corresponds to or closely follows green ring and can be positively identified only with magnification.
Parboiled rice - Rough rice soaked in warm water under pressure, steamed and dried before milling.
Parboiling - A process by which rough rice is steeped in water, steamed or heated to gelatinize starch, then subsequently dried.
Pathogen - A specific agent that causes infectious disease.
Pest - An organism that competes with humans.
pH - A measure of the acidity or alkalinity of soil, water or solution. Values range from 0 to 14 with 7 being neutral, less than 7 acidic and above 7 alkaline.
Photosynthesis - The process by which plants absorb light and use the energy for growth and development.

Phytotoxic - Causes toxic or harmful effects on a plant.

Pollination - Transfer of pollen from the male to female flower structures.

Precooked rice - Milled rice which has been processed by various methods to make it cook quickly.

Processed rice - Rice used in breakfast cereals, soups, baby foods and packaged mixes.

Pupa - The third stage of insects with complete metamorphosis (egg, larva, pupa, adult). Pupae do not feed and are in a resting stage.

Radicle - First root of a germinating seed.

Ratoon crop (second crop) - Regrowth of rice from the stalks harvested earlier.

Resistance - The inherent ability of a host plant to suppress, retard or prevent entry or subsequent activity of a pathogen or other injurious factor.

Rice bran - Layer directly beneath the hull containing the outer bran layer and parts of the germ. Bran is rich in protein and vitamin B. It is used as livestock feed and vitamin concentrates.

Rice polish - A layer removed in the final stages of milling which was composed of the inner white bran. It is rich in protein and has high fat content; used in livestock feed and baby food.

Rough rice (paddy) - Rice grains with the hulls, but without any part of stalk; consists of 50 percent or more of paddy kernels (whole or broken unhulled kernels of rice).

Saturated - Condition when all soil pore spaces are full of water.

Sclerotium (pl. sclerotia) - Dense, compacted mass of hyphae, resistant to unfavorable conditions and can remain dormant for long periods; able to germinate when favorable conditions return.

Screenings - Broken milled rice which is less than one-half of the whole kernel and more than one-quarter of the whole kernel.

Second heads - Largest size of broken milled rice which is more than one-half of the whole kernel size.

Semidwarfs - Plants changed genetically to a reduced plant height.

Senescence - The process of aging leading to death after the completion of growth in plants and individual plant parts.

Shoot - A collection of leaves originating from a crown in rice before stem formation occurs.

Short-grain rice - Rice that is almost round. Kernel size ranges from 4.56 to 5.01 mm in length, and the length-width ratio varies from 1.66 to 1.77:1.

Skipper - A group of insects closely related to moths and butterflies. Adult skippers have knobs on the end of their antennae (similar to butterflies), and the antennae are widely spaced on the head (similar to moths).

Spikelet - Consists of a single floret below which are two reduced bracts.

Spore - A minute propagative unit that functions as a seed, but differs from it in that a spore does not contain a preformed embryo.

Stale seedbed - Seedbed prepared about planting time in which vegetation is allowed to grow usually.

Stooling - Tillerng.

Straighthead - Physiological disorder characterized by sterile, deformed seeds and an upright seedhead.

Sun checking - Fissuring.

Susceptibility - The inability of a plant to resist the effect of a pathogen or other damaging factor.

Suppression - The act of reducing or holding back rather than eliminating.

Tiger moth - A group of moths with hairy caterpillars (the woollybear).
**Tiller** - A young vegetative shoot arising from nodes at the base of the plant; most can produce a panicle.

**Tillering** - The period during which tillers are formed, usually beginning at the 4- to 5-leaf stage and continuing until early reproductive growth.

**Tolerance** - Amount of pesticide that can safely remain in or on raw farm products at time of sale, or the ability of a plant to yield equally under diseased condition as healthy.

**Total milling yield** - Pounds of head, brewers, second heads and screenings milled from 100 pounds of rough rice.

**White rice** - Total milled rice after the hulls, bran layer and germ are removed. This includes head rice and broken.

**Y-leaf** - The most recently expanded leaf, at least 3/4 unfurled. This leaf is usually selected for tissue analysis.
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