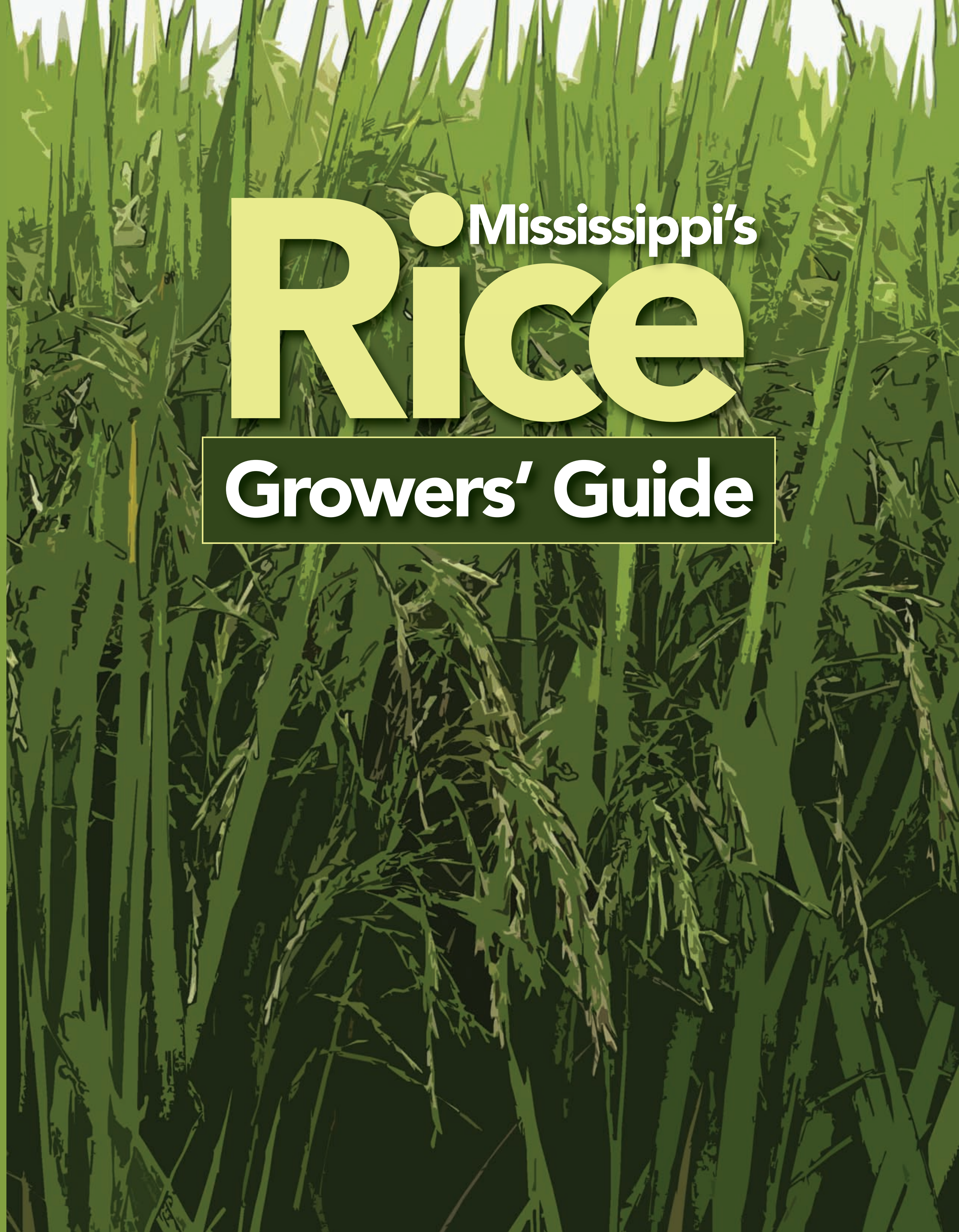
Mississippi's Rice Growers' Guide



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CHAPTER 1
INTRODUCTION

Theodore Miller and Joe Street

Mississippi is the fourth-largest rice-producing state, after Arkansas, Louisiana, and California. Mississippi's modern commercial rice production began in 1948 when Rex Kimbrell produced about 300 acres just south of Greenville in Washington County. The next year, about 5,000 acres were harvested. By 1954, about 77,000 acres were harvested. After the 1954 crop, the U.S. government instituted acreage controls, and only 52,000 acres were harvested in 1955. Because Mississippi did not have a long history of rice production, the acreage allowed under the federal acreage control program stayed very low for the next 18 years. Under this program, the number of acres harvested varied from a low of 31,000 in 1957 to a high of 67,000 in 1968. Rice culture in the Mississippi Delta was limited by this government program, not producer interest. After the acreage control program was eliminated in 1973, the harvested acreage increased to 108,000 acres in 1974. In the following years, rice production increased rapidly, reaching a high of 335,000 harvested acres and 14.4 million hundredweight (cwt) in 1981. Since then, rice acreage has stabilized at about 250,000 acres.

Rice production in Mississippi has been almost totally limited to the Mississippi-Yazoo Delta, with very little production outside this area. The central-Delta counties of Bolivar, Washington, and Sunflower have been the leading rice-producing counties. Their clay soils, large and flat fields, high quality of available water, and climate are excellent for rice growth.

Farmers who moved to the Delta from the rice-producing areas of Louisiana, Arkansas, and Texas produced most of the early rice. Producers brought their own cultural practices with them, but not all of these practices worked well in the Mississippi Delta. A small rice research project was started at the Delta Branch Experiment Station in 1950 to determine adapted cultivars and best practices for the Delta. At first, responsibility for the project was divided among three existing projects, with leadership assigned to the corn and small grains project. The first meeting of Mississippi rice producers was held at the Delta Branch Experiment Station in August 1951. In 1958, a separate rice project was established. When rice acreage began to expand in 1974, scientists were added to the rice project.

The Mississippi Rice Grower's Guide provides an overview of Mississippi rice production practices. This publication includes the most recent research findings from Mississippi State University and other rice-growing states. The Mississippi Rice Promotion Board funded much of this information through grower check-off funds.

MISSISSIPPI Rice Promotion Board

Rice Growth and Development

Nathan Buehring

Under favorable soil and temperature conditions, rice plants may grow for several years. But in the United States, they are seeded annually. Rice is a native of the tropics and is best adapted to an aquatic habitat with high temperatures and humidity.

Rice growth can be divided into three stages of development:

1. Vegetative
2. Reproductive
3. Grain filling and ripening

Each stage of development helps determine rice grain yield. There are three factors that determine rice grain yield:

1. Number of panicles per unit of land area.
2. Number of grains per panicle.
3. Weight of individual grains.

Vegetative Stage

The vegetative stage includes germination, emergence, seedling establishment (pretillering), and tillering. This very important stage in rice development determines the number of panicles per unit of land area. The period ends when the internodes begin to elongate.

1. Seed germination: This process begins when the seed absorbs water and becomes soft and elastic. **Note:** Before you apply Delayed-PRE of either Bolero or Prowl, the seed must have soaked up enough water for germination. Once the seed has soaked up water, the radicle or coleoptile will begin to elongate. The radicle emerges first under dry-seeded, or aerobic, conditions. The coleoptile emerges first under water-seeded, or anaerobic, conditions. Germination can occur within a few of days of seeding when temperatures are between 70 and 100 ˚F. When temperatures are below 70 ˚F, germination can take longer.

2. Seedling emergence (spiking): Spiking occurs once the coleoptile has emerged through the soil. If the seed is covered with both soil and water, lack of oxygen may reduce seedling emergence. Seedling emergence depends on temperature and environment. Warm temperatures and good growing conditions can lead to seedling emergence in less than a week. Seedling emergence can take 2 to 3 weeks in cooler temperatures. Figure 2.1 is a diagram of a seedling rice plant.

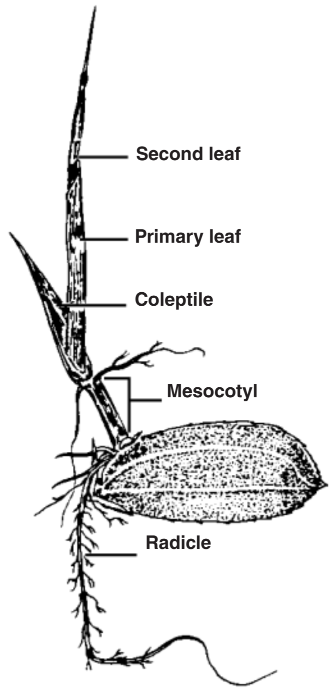


Figure 2.1. Seedling rice plant.

3. Seedling establishment (pretillering): Pretillering lasts from the development of the first leaf to the development of the fourth leaf. Roots grow and develop during this time. The endosperm can supply the seedling with nutrients up to the three-leaf stage. If there are soil nutrient deficiencies, you will usually see their symptoms beginning at the three- to four-leaf stage.

4. Tillering: Tiller production begins when rice is at the fifth-leaf stage. Most of the vegetation is produced during this period. The number of tillers per plant depends on several factors, including cultivar, seeding rate, environment, and soil nutrients. Tillering continues until all tillers develop. Once maximum tillering has been achieved, rice goes through a vegetative lag stage and plant growth reduces.

Reproductive Stage

The reproductive stage begins with culm elongation and lasts through flower pollination. This stage usually lasts 30 days, depending on the rice cultivar. During the reproductive stage, the number of rice grains per panicle is determined, which affects yield.

1. **Panicle Initiation (PI)/Green Ring Stage:** During this period, panicle production begins on the uppermost node of the culm. At this time, the nodes are "stacked," with very little distance between them (Figure 2.2). This period is also called the green ring stage because of the green band slightly above the top node. The green band is only present for a couple of days and indicates the beginning of internode elongation. Usually, panicles form 3 to 4 weeks before they are noticeable in the field. The panicle emerges from the plant about 22 to 33 days after internode elongation. See Figure 2.2.

2. **Internode Elongation/Jointing:** Once the panicle is produced, the top node begins to elongate and move up the stem, increasing the space between nodes, or internode length. Other internodes begin to elongate soon afterward. See Figure 2.2.

3 **Panicle Differentiation (PD):** This stage occurs when there is approximately ½ to ¾ inch internode elongation on the first panicle. This is a critical time in the reproductive stage because the panicle is sensitive to environmental factors that can affect the number of grains per panicle. See Figure 2.2.

4. **Booting:** Booting occurs when the panicle grows up through the leaf sheath. The flag leaf and sheath begin to swell. During late boot, the flag leaf is fully extended.

5. **Heading:** The heading stage begins as the panicle emerges from culm. When heading begins, 10 to 20 percent of the panicles have emerged from the boot. Grain matures about 30 to 40 days after heading. The phrase "50 percent heading" refers to the stage when 50 percent of the panicles have emerged from the culm. Figure 2.3 shows parts of the panicle.

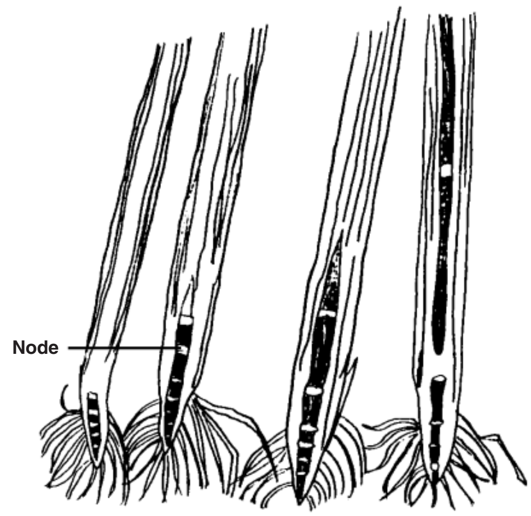


Figure 2.2. Illustration of panicle initiation, internode elongation, and panicle.

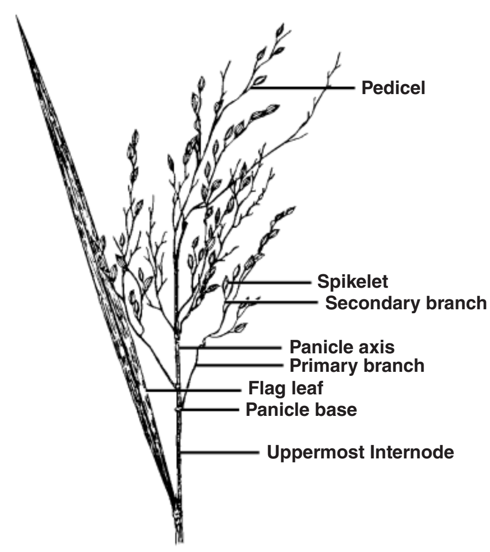


Figure 2.3. Parts of a panicle.

6. **Flowering:** Flowering begins as the panicles start to emerge from the culm. Flowering starts the first day the panicle emerges, usually 22 to 33 days from internode elongation. Flowering begins at the tip of the panicle and moves down toward the panicle base. Depending on weather and cultivar, flowering normally lasts from 6 to 10 days. Flowering usually occurs from mid-morning to just after noon. Rice is normally self-pollinated, and pollen is shed just before or at the time flowers open. Flowering slows or stops during cloudy, rainy, or cool weather. See Figure 2.4. for parts of the spikelet.

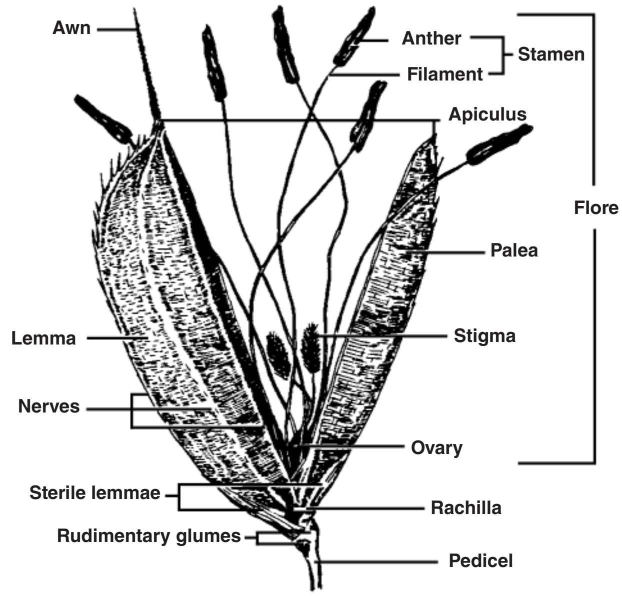


Figure 2.4. Parts of spikelet.

Grain Filling and Ripening

After flowering, the rice kernel reaches its maximum length in 12 days, its maximum width in 2 days, its maximum thickness in 28 days, and its dry weight in 35 days. Before and during kernel growth, several factors may influence its development.

These factors influence kernel development:

- Straighthead
- Cold water (can cause injury)
- Insects (stink bugs, armyworms, and others)
- Certain diseases (sheath blight, stem rot, blast, kernel smut, and others)
- Nutrient deficiency during kernel development stage
- Rainy, cloudy, or windy days during flowering period (cause poor pollination and kernel development)
- Temperatures below 55 ˚F during flowering period (cause poor fertilization and kernel development)
- Temperatures above 95 ˚F and hot, dry winds during kernel development (cause sunchecked kernels)
- Blackbirds or chewing insects (cause mechanical damage)

Kernels mature in the order that they flower, from the top of the panicle down to the base. During this ripening period, kernels go through a milky stage, where they fill with a white substance. As kernels mature, the starch in them gets harder. Kernels are mature when they reach 22 percent moisture.

CHAPTER 3
Rice Cultivars and Seed Production

Nathan Buehring, Dwight Kanter, and Theodore Miller

The goal of the rice-breeding program at Stoneville is to develop and release cultivars that are short, resist lodging and diseases, and mature early. These cultivars should produce grains that mill well and have typical long-grain cooking quality. These are the same qualities you should look for when selecting a new rice cultivar to grow. Grow a new cultivar on a limited acreage at first so you can see how it fits into the overall farming operation. Historically, only long-grain cultivars have been grown in Mississippi, so only long-grain cultivars are discussed below. Table 3.1 describes commonly grown long-grain rice cultivars in terms of yield and physiology.

Bowman

Bowman is a high-yielding, long-grain, semi-dwarf variety released by Mississippi State University in 2007. Bowman has excellent cooking qualities that are similar to Dixiebelle's and Sabine's. Bowman heads and matures a couple of days later than Cocodrie does. Bowman is susceptible to blast and sheath blight.

CL 131

CL 131 is a long-grain, semi-dwarf variety released by Horizon Ag in 2004. CL 131 is a Clearfield variety resistant to Newpath and Beyond herbicides. CL 131 has excellent milling qualities. Data collected in 2005 and 2006 indicate that CL 131 yields about 6 bushels per acre more than CL 161. CL 131 matures earlier than CL 161. This variety is very susceptible to sheath blight. It is less likely to lodge than CL 161.

CL 161

CL 161 is a long-grain variety released by Horizon Ag in 2001. CL 161 is a Clearfield variety and resistant to Newpath and Beyond herbicides. It has excellent milling qualities. CL 161 heads about 1 day after Cocodrie. It matures about 3 days after Cocodrie. This variety is also very susceptible to sheath blight and is more likely to lodge than Cocodrie.

CL 171-AR

CL 171-AR is a long-grain variety released by Horizon Ag in 2007. CL 171-AR is a Clearfield variety and resistant to Newpath and Beyond herbicides. CL 171-AR has good milling qualities. CL 171-AR heads about 2 days later than CL 161 and matures similarly to CL 161. This variety is also very susceptible to sheath blight and has less potential to lodge than CL 161.

Cocodrie

Cocodrie is a high-yielding, long-grain, semi-dwarf variety released by Louisiana in 1998. Cocodrie heads and matures about 2 days earlier than Wells. Cocodrie is susceptible to sheath blight and kernel smut and moderately resistant to blast.

Cybonnet

Cybonnet is a high-yielding, long-grain variety released by Arkansas in 2003. Cybonnet is about as tall as Cocodrie is and has excellent milling qualities. This variety is very susceptible to sheath blight and moderately resistant to blast.

Sabine

Sabine is a long-grain, semi-dwarf variety released by Texas in 2004. Sabine has excellent milling and cooking qualities. This variety is susceptible to sheath blight and very susceptible to kernel smut.

Trenasse

Trenasse is an early-maturing, semi-dwarf variety released by Louisiana in 2005. Trenasse has below-average milling qualities. Trenasse is very susceptible to sheath blight and lodging.

Wells

Wells is a high-yielding, long-grain variety released by Arkansas in 1998. Wells has average milling qualities. Wells is moderately susceptible to sheath blight and susceptible to blast. Wells is moderately resistant to kernel smut and susceptible to false smut.

XL 723

XL 723 is a high-yielding rice hybrid released by RiceTec in 2004. This hybrid matures similar to Cocodrie. XL 723 has average milling quality and has a greater potential to lodge than Cocodrie. XL 723 is resistant to blast and moderately susceptible to sheath blight.

Table 3.1. Average agronomic and milling data of cultivars grown in on-farm test from 2001 to 2007.										
Cultivar	Grain Yield (averaged over 3 years[a])	Milling Yield[b] Whole	Milling Yield[b] Total	Bushel Weight	Plant Height	Days to Heading	Days to Maturity	Lodging	1000 Seed Weight[c]	Sheath Blight Rating[d]
	bu/A	%	%	lb	in			%	g	%
Bowman	212	53.8	68.5	43.6	39	83	131	8	25.7	6
CL 131[e]	174	60.0	69.7	42.9	35	89	133	19	23.1	9
CL 161	168	64.0	72.0	42.0	40	84	132	38	21.8	26
CL 171-AR	181	54.2	68.9	43.9	40	86	131	4	23.1	9
Cocodrie	194	61.4	71.3	42.2	40	82	129	14	23.9	27
Cybonnet	178	65.4	74.5	43.8	39	85	129	20	24.0	6
Sabine	190	60.7	70.6	43.4	38	85	131	17	24.4	5
Trenassee	178	52.3	65.5	40.5	40	81	127	42	25.5	6
Wells	198	56.8	73.1	43.6	42	82	129	18	25.3	23
XL 723	202	59.7	70.8	39.4	44	81	131	27	26.3	7

[a]Average yield from 3 most recent years of testing.

[b]Values for milling and agronomic characteristics are accumulated means over all years of testing.

[c]Weight in grams of 1000 kernels at 12% moisture.

[d]Sheath blight score using average percent of all plants infected on a plot basis.

[e]Only 2 years of data.

Rice Seed Production

Seed Quality and Classification

Quality rice seed is well matured. It is free from red rice; immature, hulled, or broken grains; seed of other cultivars; weed seeds; and other foreign matter. Poorly germinated seed causes uneven stands, uneven ripening, low yields, and poor milling quality. To ensure high quality, purchase genetically pure seeds. Plant Mississippi-certified seed or seed of equal quality.

The Foundation Seed Stocks program and the Mississippi Crop Improvement Association Seed have established seed certification standards. To develop a new variety or maintain the purity of older cultivars, the breeder selects single rice panicles to be grown in rows called headrows. The breeder selects rows that are typical of the variety and combines them to produce breeders' seed. The breeders' seed is provided to the Foundation Seed Stocks unit, which uses it to produce Foundation Seed.

Rice Seed Certification Standards

Application of General Seed Certification Standards

The General Seed Certification Standards and the following specific standards make up the standards for rice seed certification in Mississippi.

Classes of Certified Rice Seed

Breeder: Seed directly controlled by the sponsoring plant-breeding organization, institution, person, or representative of the sponsor.

Foundation (White Tag): First year's production from breeder seed.

Registered (Purple Tag): First year's production from foundation seed.

Certified (Blue Tag): First year's production from registered seed.

Cultivars Per Farm

If you grow more than one variety on your farm, the Mississippi Crop Improvement Association (MCIA) must inspect between cultivars all equipment used in harvesting, hauling, and storing.

Land Requirements

Fields offered for certification must have the following rotation of crops:

Foundation: 1 year rice and 2 years another crop (or summer fallow)

Registered: 1 year rice and 1 year another crop (or summer fallow)

Certified: 1 year rice and 1 year another crop (or summer fallow)

Application for Field Inspection

Applications for field inspection must be filed with the MCIA by July 1.

Isolation

Certified fields should be isolated from neighboring fields of other cultivars or non-certified fields. Separations should be at least 15 feet if the adjacent fields are drilled seeded, 50 feet if ground broadcast, and 100 feet if aerially seeded.

Field Inspection

Fields are inspected after heading and before harvest. You must supply the inspector with transportation for inspecting the fields.

Fields heavily infested with a disease that cannot be controlled easily with a seed treatment may be rejected for certification. When a foundation or registered field is rejected for red rice contamination, the field cannot be rogued and reinspected for red rice.

Sampling

You can stack no more than 1,000 50-pound bags, or an equal amount, in a lot for the purpose of drawing official sample unless you get special permission.

To test for red rice for the Foundation Class, an MCIA inspector draws a 2-pound sample from each lot of cleaned seed and a 2-pound sample of rejected seed. Rejected seed comes from the cleaning process, which may remove medium and short grain seed. The samples are hulled and tested for red rice.

To test for red rice for all other classes, the MCIA inspector draws a 1-pound sample from each lot of cleaned seed. The samples are then hulled and tested.

Seed Samples for Laboratory Analysis

An official sample for laboratory analysis is drawn from each lot of cleaned seed to be certified. A representative of the MCIA will draw this sample if you request it.

Official sampling in bulk is allowed if a representative sample can be drawn and seed is shallow enough for MCIA sampling equipment. MCIA reserves the right to limit the quantity in a given lot of seed. If 60 days pass between the date of the bulk sample for germination and the date of the second sample from the cleaned seed for purity, a complete analysis is required. If you do official sampling in bulk, you must submit a post-processing sample to the State Seed Testing Laboratory to fulfill the germination requirements of the Mississippi Pure Seed Law.

CHAPTER 4

Rice Stand Establishment

Nathan Buehring, Tim Walker, and Jason Bond

Maximum rice yield begins with a sufficient stand of rice. Stand establishment is affected by many factors, including cultivar selection, seedling vigor, seeding date, seeding rate, seed treatments, environment, and geographic location. Uneven emergence results in an uneven rice crop. Management decisions may be difficult for the rest of the growing season because of the variety of growth stages. Uniform rice emergence is also important for accurate DD50 predictions of growth stages.

Seed Bed Preparation

A smooth, weed-free seedbed is a must for dry-seeding rice. In a continuous rice culture, the field should be disked or rolled in the fall to help start rice straw decomposition. There are several ways to remove and smooth the old levees in the field. Do this to get rid of potholes and rough areas in the field before disking. It takes less time to prepare land in a rice and soybean rotation because soybean harvest usually leaves the soil in good condition. This is especially common in an early soybean production system. For a smooth seedbed at planting in the spring, do most of the tillage operations in the fall with only minimal tillage in the spring before planting. Fall disking and light spring tillage provide the best seedbed for planting rice. If clods are a problem, use a drag pipe or corrugated roller to firm the seedbed. A fall or spring burndown herbicide application may be necessary to control winter weeds and eliminate another tillage operation. See the Rice Weed Control section for specific winter weed control recommendations. Always check herbicide labels for rotation restrictions with herbicides that have been applied to a specific field in previous crops. See Table 4.1 for herbicide rotation restrictions when planting rice.

Seeding Rate

Cultivars

Seeding rates for rice vary slightly among cultivars because of differences in seed weight and size. Table 4.2 lists the number of seed per square foot at specific seeding rates for common Mississippi cultivars. As a general rule, about 60 to 70 percent of the rice seed planted will germinate and emerge. The optimum stand density ranges from 12 to 20 plants per square foot. If carefully managed, a uniform stand of more than six plants per square foot can produce satisfactory yields. To achieve the optimum density, there are things to consider besides seeding rate. The following strategies also encourage optimum germination rates:

- Planting when the soil temperature averages 60 ˚F or greater
- Planting seed treated with fungicide, such as Apron XL LS
- Rolling to increase seed-to-soil contact
- Planting into a firm and smooth seed bed

Under optimal conditions, seeding rates as low as 40 pounds per acre can result in a sufficient plant population (more than 12 plants per square foot) with yields comparable to a seeding rate of 100 pounds per acre. Table 4.3 compares seeding rates and corresponding plant populations to yield among common rice cultivars. The table shows that a seeding rate of 40 pounds per acre can result in yields similar to 100 pounds per acre for each of the cultivars. It also shows that more than seven plants per square foot can produce rice yields comparable to the yields of higher plant populations. Lower seeding rates can work if the stand is uniform. The strategies mentioned increase the chances of a uniform stand. Here are some advantages to lower seeding rates:

- Seed Cost: Reducing seeding rates reduces seed cost, especially for hybrid cultivars. Most producers think a high seeding rate is a form of cheap "insurance." But a high seeding rate of a Clearfield cultivar can be very costly. Reducing the seeding rate can reduce seed cost but maintain high yields.
- Disease Pressure: A lower seeding rate could reduce the potential for diseases such as sheath blight. Thinner stands can increase airflow through the canopy, which discourages diseases.
- Lodging Potential: A lower seeding rate could reduce the potential for lodging, especially with taller cultivars.

Table 4.1. Herbicides and Crop Rotation Restrictions

Herbicide Common Name	Trade Name	Rice Rotation Restriction
Atrazine	Aatrex (and many others)	Following year. If you apply after June 10, plant rice the second year.
Atrazine + Metolachlor	Bicep II Magnum	15 months
Chlorimuron	Classic	9 months
Clethodim	Select	30 days
Clomazone	Command	Less than 2 pts: anytime Greater than 2 pts: 9 months
Chloransulam	Frontrow	6 months
Dimethenamid	Outlook or Frontier	Following year
Diuron	Karmex (Many Others)	Following year
Fluazifop	Fusilade	60 days
Flumetsulam	Python	9 months
Fluometuron	Cotoran (Many Others)	6 months
Flumioxazin	Valor	0 - 2 oz: 30 days 2 - 3 oz: 2 months plus 1" of rainfall
Fomesafen	Reflex	10 months
Imazaquin	Scepter	Following year
Imazethapyr	Newpath	18 months
Metolaclor	Dual	Next spring
Metribuzin	Sencor/Lexone	8 months
Metribuzin + Chlorimuron	Canopy	pH less than 7.0: 10 months pH 7.1 to 7.5: 18 months
MSMA	Various Formulations	None, but take precautions for straighthead
Nicosulfuron	Accent	pH less than 6.5: 10 months pH greater than 6.5: 18 months
Oxyfluorfen	Delta Goal	10 months
Pendimethalin	Prowl, Pendimax	Following year
Primisulfuron	Beacon	18 months
Prometryn	Caparol	Following year
Pyrithiobac	Staple	9 months
Quizalofop	Assure II	120 days
Trifluralin	Treflan (Many Others)	Following year, 2 years for 2X rate
Trifloxysulfuron	Envoke	7 months
Trifloxysulfuron + Prometryn	Suprend	7 months

Table 4.2. Rice seeding chart for different rice cultivars and seeding rates								
		Seeding Rate (lbs/A)						
Variety	Seed/lb	50	60	70	80	90	100	110
		Number of Seed/ft^2						
Bowman	17700	20	24	28	33	37	41	45
CL 131	19654	23	27	32	36	41	45	50
CL 161	20826	24	29	33	38	43	48	53
Cl 171-AR	19654	23	27	32	36	41	45	50
Cocodrie	18996	22	26	31	35	39	44	48
Cybonnet	18917	22	26	30	35	39	43	48
Sabine	18606	21	26	30	34	38	43	47
Trenasse	17804	20	25	29	33	37	41	45
Wells	17945	21	25	29	33	37	41	45

		Seeding Rate (lbs/A)			
Hybrid	**Seed/lb**	**25**	**30**	**35**	**40**
		Number of Seed/ft^2			
XL 723	17262	10	12	14	16

Table 4.3. The influence of seeding rate on plant density and rough rice yield.								
Seeding Rate (lb/A)	Cocodrie		Francis		Priscilla		Wells	
	Density[a]	Yield[b]	Density[a]	Yield[b]	Density[a]	Yield[b]	Density[a]	Yield[b]
20	7	216	7	220	7	213	8	217
40	16	230	16	221	10	225	14	233
60	21	230	19	227	16	229	22	233
80	28	227	25	225	24	232	27	228
100	29	234	34	234	31	221	31	230

[a]**Plants/ft2**

[b]**Bushels/A**

Source: Bond et al. 2005. Seeding rates for stale seedbed rice production in midsouthern United States. Agron. J. 97:1560-1563.

There are some disadvantages to lower seeding rates. One disadvantage is that a lower seeding rate can reduce rice competition with weeds. This is a common problem with semi-dwarf cultivars because they already compete less than taller cultivars do. Thin stands of a semi-dwarf variety compete even less where weeds are dense.

Another disadvantage is increased rice water weevil pressure. As the rice stand density decreases, the likelihood of having problems with rice water weevils increases. If you use a low seeding rate, you may need to apply an insecticide at flooding.

Hybrids

Hybrid rice cultivars can be planted at a lower seeding rate than a conventional cultivar can be because hybrids can tiller profusely. A seeding rate of 30 to 35 pounds per acre generally results in an optimum stand density of 9 to 12 plants per square foot for hybrids. The key for successful hybrid production is uniform emergence and stand. If rice emergence is not uniform, the different levels of maturity can harm rice milling.

Getting a uniform stand can be difficult with hybrids, especially with these low seeding rates. Use suggestions listed earlier for optimum germination rates. Under very thin and nonuniform stands, replanting may be necessary. But plant stands of 3 plants per square foot can provide acceptable yields because hybrids have such a high tillering capacity. Table 4.2 lists the number of seed per square foot at specific seeding rates for common Mississippi hybrids.

Row Spacing

Rice is often planted with a grain drill at a row spacing of 6 to 10 inches. These row spacings can produce similar yields. However, narrower drill row spacings tend to produce higher yields. A drill spacing of 6 to 8 inches is best. When changing row spacings, seeding rates do not need to be adjusted. Table 4.4 provides the number of seed per foot for 6 to 10 inch drill row spacing and seeding rates for drill calibration.

Table 4.4. Seed Spacing for Calibrating Drills.

	Row Spacing				
Seed/ft^2	6"	7"	8"	9"	10"
	(Seed per row foot)				
10	5	6	7	8	8
15	8	9	10	11	13
20	10	12	13	15	17
25	13	15	17	19	21
30	15	17	20	23	25
35	18	21	23	26	29
40	20	23	27	30	33
45	23	26	30	34	38
50	25	29	33	38	42

Seed Treatments

Most seed dealers in Mississippi offer seed treatments on all grades of seed. Seed treatments are fairly inexpensive and can optimize germination rates. Fungicides and growth regulators are the most common seed treatments. Base seed treatment decisions on planting date, seedbed condition, cultivar, and field history.

Fungicide seed treatments are often helpful when rice is planted early, especially on clay soils. They are also beneficial if the field has a history of seedling diseases. If conditions promote fungi, a fungicide seed treatment can increase germination by 10 to 20 percent. Fungicide seed treatments do not increase the speed of germination like a growth regulator does or protect against diseases throughout the growing season. See Table 4.5 for registered seed treatments and their recommended rates, fungi they control, and application methods.

Today, the only recommended growth regulator seed treatment is gibberellic acid (GA). Seed treated with GA is recommended on semidwarf cultivars, cultivars with poor seedling vigor, clay soils, and rice planted early. GA-treated seed promotes uniform emergence and quick germination and emergence. Rice seedlings may appear tall and yellow after emergence when GA is used; these symptoms reduce in 1 to 2 weeks. Gibberellic acid does not protect the seed from any of the common seedling diseases. You may use fungicide with GA, but read label instructions before use.

Table 4.5. Recommended rice fungicide seed treatments				
Disease	Fungicide	Active Ingredient	Rate/cwt Seed	Comments
Pythium diseases	Allegiance FL (formerly Apron)	metalaxyl	0.75 - 1.5 fl oz	Apply with commercial seed-treating equipment.
	Apron XL LS	mefenoxam	0.32 - 0.64 fl oz	Apply with commercial seed-treating equipment. Use higher rates for early planting or other severe disease situations.
Rhizoctonia seedling diseases, general seed rots	RTU-Vitavax-Thiram	carboxin + thiram	6.8 fl oz	Apply with commercial seed-treating equipment or use as a pour-on hopper-box treatment.
	Vitavax 200	carboxin + thiram	4 fl oz	Apply with commercial seed-treating equipment.
	Maxim 4 FS	fludioxonil	0.08 - 0.16 fl oz	Apply with commercial seed-treating equipment. Use higher rates for severe disease.
	Trilex FL	trifloxystrobin	0.32 - 0.64 fl oz	Apply with commercial seed-treating equipment.
	Dynasty	azoxystrobin	0.153 - 1.53 fl oz	Apply with commercial seed-treating equipment.
Pythium, Rhizoctonia, general seed rots	Vitavax 200 + Allegiance FL (formerly Apron)	carboxin + thiram + metalaxy	4 fl oz + 0.375 fl oz	Apply with commercial seed-treating equipment.
	Apron XL LS + Maxim 4 FS	mefenoxam + fludioxonil	0.32 - 0.64 fl oz + 0.08 - 0.16 fl oz	Apply with commercial seed-treating equipment. Use higher rates for early planting or severe disease.
	Stiletto	carboxin + thiram + metalaxyl	6.8 fl oz	Apply with commercial seed-treating equipment.
	Trilex FL + Allegiance FL	trifloxystrobin + metalaxyl	0.64 fl oz + 0.64 fl oz	Apply with commercial seed-treating equipment.

Seeding Date and Soil Temperature

Do not plant rice until the average 4-inch soil temperature is 60 ˚F. This normally occurs around April 1 in Stoneville and April 5 in Tunica. The higher the soil temperature, the less time seed takes to emerge. When the average soil temperature is 60 ˚F and there's enough moisture, rice should emerge in 2 to 3 weeks. Once the average soil temperature reaches 70 ˚F, the time between seeding and emergence should be 1 week. Production costs may increase because of flushing and weed control when rice is planted at a soil temperature lower than 70 ˚F.

Table 4.6 lists the optimum planting dates for rice cultivars commonly grown in Mississippi. In the southern Delta, the best time to plant rice is from April 1 to about May 20, depending on the cultivar. In the northern

Delta, the best time is from April 5 to May 15. These dates are based on averages and may change based on the weather during planting season.

Rice can be planted after wheat or fields that were precision graded in the spring. If you must plant rice in June, choose a cultivar that is suited for late planting. Studies in Mississippi show that Priscilla or any of the hybrids are suitable for late planting. Remember that rice planted in June usually has a lower yield potential than rice planted in April or May.

If you plant rice on a large acreage, consider using different cultivars and staggering the planting dates so that rice matures at different times and can be harvested as it matures. Table 4.7 estimates maturity for different emergence dates and rice cultivars.

Post Seeding Management

Rolling

Rolling behind drilled rice increases stand density because it increases seed-to-soil contact. If the soil is cloddy at planting, always use a roller behind the drill.

Levee Surveying and Construction

Generally, levees are surveyed on a contour at vertical intervals of 0.1 to 0.2 foot between levees. The vertical interval is usually 0.2 foot between levees. If a small acreage is on a steep slope (2 to 4 percent slope), either place levees at 0.3 to 0.4 foot vertical intervals or convert to another crop. When surveying, a shallow furrow is commonly made on a contour of the vertical intervals. The furrow acts as a guide for levee construction. The proper location of levees depends on the experience of the surveyor or operator and the accuracy of the instrument.

Where fields have been land formed for straight levees and the grade has been maintained, you can simply place levees with a measured distance between them.

Table 4.6. Optimum planting dates for selected cultivars that are commonly grown in Mississippi.

	South Delta		North Delta	
Cultivar	Optimum[a]	Cutoff	Optimum[a]	Cutoff
Bowman	April 1 - May 20	June 15	April 5 - May 15	June 10
CL 131	April 1 - May 15	June 10	April 5 - May 10	June 5
CL 161	April 1 - May 20	June 15	April 5 - May 15	June 10
CL 171-AR	April 1 - May 20	June 15	April 5 - May 15	June 10
Cocodrie	April 1 - May 15	June 10	April 5 - May 10	June 5
Cybonnet	April 1 - May 15	June 10	April 5 - May 10	June 5
Sabine	April 1 - May 15	June 10	April 5 - May 10	June 5
Trenasse	April 1 - May 15	June 10	April 5 - May 10	June 5
Wells	April 1 - May 20	June 15	April 5 - May 15	June 10
XL 723	April 1 - May 20	June 15	April 5 - May 20	June 15

[a]These suggested planting dates do not guarantee high yields or prevent a crop failure. Rice can be planted before April 1 but not before March 25 in the southern Delta region. Rice can be planted before April 5 but not before April 1 in the northern Delta region.

Table 4.7. The predicted maturity date as influenced by the emergence date and cultivar[a]						
	Rice Emergence Date					
Cultivar	April 15	April 25	May 5	May 15	May 25	June 5
	Predicted Maturity Date[b]					
Bowman	Aug. 20	Aug. 25	Aug. 30	Sept. 7	Sept. 16	Sept. 29
CL 131	Aug. 20	Aug. 25	Aug. 31	Sept. 7	Sept. 16	Sept. 29
CL 161	Aug. 22	Aug. 27	Sept. 3	Sept. 10	Sept. 19	Oct. 4
CL 171-AR	Aug. 19	Aug. 24	Aug. 30	Sept. 7	Sept. 16	Aug. 22
Cocodrie	Aug. 20	Aug. 25	Aug. 30	Sept. 7	Sept. 16	Sept. 29
Cybonnet	Aug. 19	Aug. 24	Aug. 30	Sept. 7	Sept. 15	Sept. 28
Sabine	Aug. 20	Aug. 25	Aug. 31	Sept. 7	Sept. 16	Sept. 29
Trenasse	Aug. 18	Aug. 23	Aug. 29	Sept. 6	Sept. 14	Sept. 27
Wells	Aug. 20	Aug. 26	Sept. 1	Sept. 8	Sept. 17	Sept. 30
XL 723	Aug. 21	Aug. 26	Sept. 1	Sept. 8	Sept. 17	Oct. 1

[a]Using weather norms from Stoneville, MS.

[b]Approximate date when rice will be at 20% moisture.

Levees must be well placed and well made to maintain a uniform water depth within each bay. In fields where levees run parallel to prevailing winds, build at least one wind levee at a right angle with the prevailing wind. Wind levees are especially important in a large bay. These levees are not tied into the perimeter or field levees. The purpose of the wind levee is to keep the wind from "stacking" the flood on one end of a large bay.

After planting dry seed, start levee construction over the contour furrow right away. Finish the operation as quickly as possible. If levee construction is delayed or prolonged rains occur after you make only one or two passes, construction will be very difficult. On heavy clay soils, you'll probably have to make four to five passes with a levee disk to reach the desired levee height of 20 to 24 inches.

You can compact the levee with tractor tires or a commercial levee packer. A levee should be compact and high enough to hold a 3- to 6-inch flood. Plan for the levee to settle after several rains.

On silt loam soils, levees should be seeded just before the final trip with the levee disk. On clay soils, levees should be seeded just after the last pass. Levees on clay soils should be packed with a spool-shaped levee packer before they are planted to keep seed from being placed too deep because of large loose clods. Levees are often seeded with a seeder mounted on the front of a tractor or above the levee plow, a pull-type grain drill, or a back-mounted seeder. The front-mounted seeder allows you to seed the levees and make the final pass with the levee disk at the same time.

After you've finished the field levees, build and seed the perimeter levee similarly. Join field levees with the perimeter levee about 7 to 10 days before an anticipated flooding. A backhoe or a small tractor with a blade does an excellent job.

CHAPTER 5

DD50 Rice Growth and Management Predictions

Nathan Buehring, Mark Silva, and Lyle Pringle

The DD50 program is a management tool developed by the National Weather Service to predict the development of the rice plant through its vegetative and reproductive stages. Weather information is collected on a daily basis across the state and tabulated by computer. The program is based on an accumulation of the high and low daily temperatures, with a base temperature of 50 °F. The following equation describes how DD50's are calculated:

$$DD50 = \frac{[\text{Daily Maximum} + \text{Minimum Temperature}] - 50}{2}$$

If maximum temperature is greater than 94 ˚F, use 94 for maximum temperature.

If minimum temperature is less than 70 ˚F, use 70 for minimum temperature.

You can find the DD50 program on the Mississippi State University Extension Service's website, **http://ext.msstate.edu/anr/drec/weather.cgi.** This will allow real-time weather and more accurate predictions.

To use the DD50 program, record the cultivar name and emergence date. The cultivar list changes each year as new varieties are released and older varieties are deleted. For the most accurate predictions, record the date of the following growth stages as they occur:

- Emergence
- First Tiller
- ½ Inch Internode or Panicle Differentiation
- 50 Percent Heading
- 100 Percent Heading

Once the rice reaches one of the progressive growth stages, update the date on the web site for a more accurate prediction. Because the interactive rice DD50 program uses real-time weather data, the DD50 predictions can be updated on a daily basis or when the rice advances to the next growth stage. See example printout on next page.

As a reminder, these are just predictions. Do not make pesticide or fertilizer applications based on these forecasted dates. Any kind of stress can increase or delay these dates. There is no substitute for monitoring rice fields in person.

Example of DD50 Information

Rice Growth and Management Predictions
Mississippi State University Extension Service

Variety: CL-161

County: Bolivar	**Grower: Nathan Buehring**
Field ID: 1	**Acreage: 40**
Year: 2006	**Report Date: Sep 16th, 2006**

Date	Growth and Management Events
05/01	Emergence - Average 10 one-leaf rice plants per square foot.
05/01 - 05/08	Apply Herbicide - Apply first post application of Newpath to spike to 1 leaf rice if not applied pre-emergence.
05/01 - 05/19	Flush Fields - May need to flush field.
05/01 - 05/19	Control Insects - Control Insects: A. Armyworms; or B. Chinch bugs (may be controlled by flooding or by applying insecticide).
05/19	Apply Fertilizer - Apply 115-120 lbs Nitrogen/Acre (250-261 lbs. Urea) on a dry soil surface.
05/19	First Tiller - Tillering begins.
05/19	Control Weeds - Control weeds (Apply second application of Newpath during the 3 to 5 leaf growth stage).
05/19	Flood - Apply shallow flood.
05/19 - 05/24	Check for Water Weevils - Scout for adult water weevils (apply insecticide if necessary) unless Icon seed treatment was used.
05/23 - 06/15	Apply Post-Flood Herbicide - Begin to apply if necessary (flood must be established and stable).
06/15 - 06/19	Apply Mid-Season Herbicide - Begin checking for green ring and internode elongation. Apply mid-season herbicides (if necessary).
06/19	½ Inch Internode - Apply 45-60 lbs Nitrogen (100-130 lbs. Urea).
06/21	Control Disease - Begin scouting for sheath blight. Apply fungicide at 35% positive infestation.
06/28	Early Boot - Apply recommended fungicide, if needed, for blast or sheath blight.
07/18	Boot Split - Stop scouting for sheath blight; continue scouting for blast.
07/20	10% Heading - Start checking for Stinkbug, Armyworm, & other insect infestations with a sweep net. Apply insecticide if needed.
07/23	50% Heading - Continue to check for stinkbugs.
07/25	70 to 80% HEADING - End blast scouting or apply recommended fungicide for blast.
07/27	100% Heading - Check again for stinkbug and other insect infestations.
08/22	Stop Pumping - Stop pumping (all heads turned down - upper ¼ - ⅓ heads are straw colored. Stop insect scouting if insects are not present).
08/24	Drain Fields - Drain fields (1. On clay soils - heads turned down - upper ½ head is straw colored; 2. On silt/sandy soils - heads turned down - upper ¾ head is straw colored).
09/02	Harvest - High yields demand slow harvest speed for maximum harvesting efficiency. Also check/adjust combines several times during the day as environmental and crop conditions change.

Historical Weather Days: *0*; Real Weather Days: *125*

Rice Fertility

CHAPTER 6

Tim Walker

On Delta soils, a high rice yield depends on the right rates and timing of plant foods. Well-timed fertilization should maximize yields and minimize lodging and damage from diseases. Fertilizer needs differ according to native fertility, cropping history, source of fertilizer nutrients, cultivar, and water management.

A soil test tells you about the soil's fertility needs. If you grow rice in rotation with soybeans, collect soil samples in the late fall or early winter after the soybean crop. The flooding common in rice production changes soil chemistry, so the results are less accurate when soils are sampled after the rice crop. Sample early enough that the lab results can be processed and used for the following crop. Fields that have not been planted in rice before may be sampled the same way as any other field. Take a separate sample from any area where an unusual operation has occurred, such as areas that have been cut deeply, filled, cropped differently, or limed. Be sure to label samples taken from unusual areas. In fields where rice has been grown, sample four separate areas of the field:

- the area where water enters the field
- the center area of the field near the flood gates
- the center area of the field away from flood gates
- the area of the field or farthest from well or flood gates

Today's technology can help you decide where to sample. If you use them correctly, yield maps created from real-time data may show you other places to soil sample. If yield tends to be low in the same area of a field over a period of 2 or 3 years, that area probably has a nutrient deficiency. You can collect samples from those low-yielding areas and from higher-yielding areas.

Nitrogen

Correcting a nitrogen (N) deficiency increases plant height, panicle number, leaf size, grain number, and number of filled grains. The number of filled grains is especially important because it largely determines the yield capacity of a rice plant. The number of tillers that develop during the vegetative stage heavily influences the number of panicles. Grain number and number of filled grains are determined mostly in the reproductive stage. Overfertilizing, underfertilizing, or fertilizing at the wrong time can decrease rice yields. It is important to apply the optimum rate of N fertilizers at the appropriate growth stage for the individual rice cultivar.

Nitrogen Sources

As the rice plant develops, you may use either an ammonium or a nitrate form of N. The N source you should use depends on when you apply it. For pre-flood application, urea or ammonium sulfate is better than nitrate fertilizer. Ammonium nitrate (34-0-0) and urea (46-0-0) are equally effective at midseason. Areas where soil pH is high or organic matter is low, such as cut areas, may need ammonium sulfate, but using ammonium sulfate as a total preflood N source is a waste of money. On high pH soils, flood the field within 5 to 7 days after applying N fertilizer to avoid serious N losses because of ammonia volatilization (Table 6.1). Agrotain®, a commercially available product, decreases N losses due to ammonia volatilization and can be applied to the urea prills, but best yields are achieved by flooding in a timely manner.

Ammonium-N is relatively stable in a flooded environment and is more effective than nitrate-N. The nitrate-N may leach or evaporate as a gas under saturated conditions, a process called denitrification. Also, at this early growth stage, the rice plants can best use the ammonium form. Water management that insures a continuous flood provides the most efficient use of N.

The early season N should be applied to a dry soil surface just before flooding. Flood the field as soon as possible after N application to incorporate the N. Maintain the flood at least 3 weeks to maximize N uptake and prevent losses through denitrification and ammonia

Table 6.1. Agrotain treated urea compared to urea alone at three application times prior to flood establishment.

Source	Time (DBF[a])	Yield (bu/A)
Agrotain + Urea	0	166
Urea	0	167
Agrotain + Urea	3	169
Urea	3	163
Agrotain + Urea	10	169
Urea	10	152

[a]Days before permanent flood establishment.

volatilization. Nitrogen applied to wet soil stays on the surface and can be lost because of breakdown by soil organisms, causing denitrification or volatilization. Nitrogen applied into the flood can also be broken down and lost.

Midseason occurs when the rice plant changes from the vegetative to the reproductive growth stage. You can identify this period in the life of a rice plant by the appearance of the "green ring" and the initial elongation of the upper internodes. It's easier to identify this developmental stage using a combination of thermal energy accumulation (DD_{50}) and observation of internodes. By midseason, the physiology of the plant and a larger feeder root system at the soil surface allow faster N uptake and use. Almost all midseason N is taken up by the plants within 3 to 4 days of application. At midseason, ammonium nitrate is as effective as urea is.

To reduce herbicide injury to rice, make the midseason N application at the proper growth stage of the rice but after the herbicide application. If possible, stop the movement of water through the field to stabilize the flood before applying midseason N. Resume pumping 3 days after each midseason N application.

Nitrogen Rates

Nitrogen (N) requirements for rice vary depending on cropping history, soil type, and the rice cultivar. Recently cleared, high organic matter soils or catfish ponds will probably need little or no N the first year. About 100 to 120 pounds of N per acre should be enough the second year. Old cropland should get 150 to 180 of N pounds per acre, depending on the cultivar and soil type. Soils with CEC's higher than 20 tend to need more N than soils with lower CEC's.

Apply one-half to two-thirds of the total amount of N that will be used in the growing season on a dry soil surface just before flooding. Apply the rest at midseason. If fields can be flooded within 5 days and uniform application is not a problem, semi-dwarf cultivars often respond better when 60 to 75 percent of the N is applied preflood.

Sometimes environmental conditions do not allow for optimum fertilizer timing. For example, if rice has reached 6 to 8 inches tall and the field is wet with no dry weather in the forecast, it is sometimes better to apply 100 pounds of urea per acre and flood the field as quickly as possible. As soon the field is flooded with 2 to 4 inches of water, make a second application of urea at the rate of 100 pounds per acre. Make a third application of 100 pounds of urea per acre when the uppermost internode begins to elongate. Apply another 100 pounds of urea per acre 7 days after that. This application method is often called "spoon feeding." If N deficiencies become apparent before midseason, time the midseason N application based on the plant need, not the growth stage.

There are times when you should apply N before planting or to seedling rice. When you will be water-seeding a field and will continually hold the water across the field until maturity, apply the entire preflood N before flooding and planting. You should also apply N before planting or to seedling rice in continuous rice production. When you incorporate a lot of organic material into the seedbed, apply 50 pounds of urea (23 pounds nitrogen) per acre during seedbed preparation or when the seedling rice is 2 to 3 inches tall. When sulfur (S) is required, you can substitute 100 pounds of ammonium sulfate per acre for the 50 pounds of urea. This will supply enough N to feed the microorganisms that decompose organic material and for young rice plants before the flood is established permanently.

If for any reason the permanent flood is delayed until plants are 7 to 10 inches tall, you may need to add N. Watch closely the weed growth habit on fields where you apply N early or before planting. Using early N tends to stimulate weed growth, and you may use a residual herbicide to help control problematic grasses. You may need to flush the field to provide enough moisture to keep the young rice plants actively growing and to reactivate residual herbicides. Immediately before flooding, apply another 90 to 120 pounds of N per acre. Make midseason N application as usual.

When rice plants need N, they become stunted and yellow. This yellowing, or chlorosis, usually appears first on the lower leaves, while the upper leaves stay green. A severe N shortage in rice makes the leaves turn brown and die. The lower leaves usually turn brown, or fire, beginning at the leaf tip and moving along the midrib until the entire leaf is dead.

Table 6.2 gives N recommendations for cultivars popular in Mississippi. Subtract 10 pounds of N from the recommended N rate for every 1 percent increase in organic matter above 3.0 percent.

Nitrogen Notes

What nitrogen does:

- Gives dark green color to plants.
- Causes rapid growth.
- Increases yield of leaf, fruit, or seed.
- Increases protein content of seeds.
- Feeds soil microorganisms when they decompose low-N organic materials.

Table 6.2. Recommended N rates for cultivars grown in Mississippi

	Clay Soils			Silt Loam Soils		
Cultivar	PF	MS	BS	PF	MS	BS
	---- (lbs N/A) ----					
Bowman	120-150	30-60	0	120	45	0
CL 131	120-150	30-60	0	120	45	0
CL 161	90-120	30-60	0	90	60	0
CL 171-AR	120-150	30-60	0	120	45	0
Cocodrie	120-150	30-60	0	120	45	0
Cybonnet	120-150	30-60	0	120	45	0
Sabine	120-150	30-60	0	120	45	0
Trenasse	90-120	30-60	0	90	60	0
Wells	90-120	30-60	0	120	45	0
XL 723	120-150	0	45	120	0	45

PF = Preflood
MS = Midseason
BS = Boot Split

Phosphorus

Historically, rice seldom responded to phosphorus (P) in Mississippi, but P deficiencies have been routinely found since the mid-1990's and appear to be increasing. Here are some of the reasons yield is now responding to P fertilizers: less fertile subsoils are exposed after landforming; the pH of much of the older rice acreage is almost or greater than 7.5, which can decrease P availability; and phosphorus is mined from the soil each time grain or cotton is harvested. Rice seldom responds to P application on black, heavy clay soils after landforming. On lighter soils, P-deficient subsoil with a high clay concentration may be exposed with cuts as shallow as 6 inches. Where soil pH is 7.5 or greater, maintain high P levels according to the soil test. The critical level for soil test-P increases as soil pH increases. One way to maintain P at productive levels is to apply P-fertilizer at a rate equal to crop removal. Table 6.3 shows the amount of P that is removed with the harvested grain or lint of commonly grown crops in the Delta.

Table 6.3. Nutrients removed with the harvested portion of the crop.

Crop	Nutrients Removed		
	N	P	K
	---------- (lb/bu) ----------		
Corn	0.75	0.19	0.24
Cotton (lint lb/bale)	32.00	6.10	16.60
Rice	0.55	0.13	0.15
Sorghum (lb/cwt)	1.50	0.33	0.32
Soybean	4.00	0.35	1.20
Wheat	1.15	0.24	0.28

Phosphorus Sources and Timing

Two available P sources are Triple Superphosphate (0-46-0) and Diammonium Phosphate (18-46-0). These sources are equally effective in supplying the plant with P. The proper timing can be as important as the rate of P-fertilizer (Table 6.4).

Table 6.4. Rice yield response to application time averaged across 25, 50, and 100 lbs P_2O^5/acre.

P Timing	Yield (bu/A)		
	Site 1	Site 2	Site 3
1-Leaf	177	105	185
Preflood	128	77	173
Midseason	75	88	--
Boot	45	83	--
Untreated	14	69	176
Soil pH	8.1	7.8	6.0
Soil test P (lb/A)	9	28	11

You must apply P at the proper time to ensure optimum results. Maximum yields have been obtained when P-fertilizer is applied at the time of planting to spiking rice. However, as long as enough P is in the plant before tillering, you can get satisfactory yields. There are two good application options that should fit well into current production practices. The first option is to apply P just before planting and incorporate with either a field cultivator or the drill. The second option is to apply the P at spiking to 3-leaf rice and allow a rain or flush to incorporate the fertilizer into the soil. This method would fit especially well when no S is needed. When a low to medium rate of P is needed (30 to 40 pounds P_2O_5 per acre), 100 pounds per acre of 18-46-0 can supply the P and early season N for improved vegetative growth. However, if a high rate of P is needed (80 pounds P_2O_5 per acre), you can blend DAP (18-46-0) and TSP (0-46-0) to avoid overapplying N during the seedling stage.

Phosphorus deficiencies are noticeable about 5 to 7 days after permanent flood establishment. Common signs of P deficiency are spots in the field where the rice has slender stalks, does not tiller, and is less colorful than the dark, shiny green of well-fertilized rice. Phosphorus deficiency can also delay maturity and cause low yields. Add phosphorus only when a soil test shows a deficiency or where deep cuts were made on land-formed areas.

Flying on 100 pounds per acre of TSP or DAP can affect yield but will not give maximum yields.

Because P deficiencies seldom occur over an entire field, using variable rate technology may be cheaper than making blanket applications. This technology allows you to apply the right amount of fertilizer in the right places, which can increase yields and decrease the amount of fertilizer used.

A good soil sampling program will help identify fields or areas within fields that have a P deficiency. Table 6.5 shows the current P recommendations from the Mississippi State University Soil Testing Laboratory.

Table 6.5. MSU-ES phosphorus recommendations based on soil test-P levels

Range	lbs P/A	Recommended lbs P_2O_5/A
Very Low	0-18	80
Low	18-36	40
Medium	36-72	30
High	72-144	0
Very High	>144	0

Phosphorous Notes

What does phosphorus do?

- Helps seedlings germinate.
- Stimulates early root formation and growth.
- Gives rapid and vigorous start to plants and promotes good root growth.
- Is associated with greater straw strength.
- Stimulates blooming and aids in seed formation.
- Hastens maturity.
- Gives winter hardiness to fall-seeded grains.

Potassium

Potassium (K) levels in Delta soils are usually medium to high, and rice response to potassium in Mississippi has not been documented. If you grow rice in rotation with soybeans, remember that soybeans remove a lot of K from the soil. You must consider nutrient removal for all crops grown in the rotation, especially on lighter soils. If soybean and rice yields continue to increase and no maintenance fertilizer applications are made, rice is more likely to respond to potassium.

Rice is also more likely to respond to K after landforming light soils. Sometimes sandy horizons are exposed after topsoil is removed. In these situations, a yield response to K is more likely.

Potassium Notes

What does potassium do?

- Increases vigor and disease resistance in plants.
- Produces strong, stiff stalks, which reduce lodging.
- Plumps the grain and seed.
- Helps form and transfer starches, sugars, and oils.

Potassium deficiency symptoms are listed below.

- Leaves mottle, spot, streak, or curl, starting on the lower leaves.
- Lower leaves scorch or burn on margins and tips. Sometimes these dead areas fall out, leaving ragged edges.
- In rice, the tip of the leaf dries up or fires, starting at and proceeding down from the edge, usually leaving the midrib green.
- Rice lodges before it matures because of poor root development and straw strength.

Add potassium only when a soil test shows a deficiency.

Sulfur

Most of the soil sulfur (S) is contained in the soil organic matter. Often an S deficiency occurs after landforming. A soil needs at least 20 pounds per acre of plant-available S. You must ask for an analysis for available S when sending a soil sample to the MSU-ES soil testing lab, as analysis for available soil S is done only by request. You can correct an S deficiency with an application of gypsum the preceding fall or with ammonium sulfate during the growing season or after the symptoms occur on rice. Apply about 24 pounds of S per acre (100 pounds per acre of ammonium sulfate) to recently land formed areas. In some cases, this rate may need to be doubled to supply enough S throughout the growing season. You may make maintenance applications of S in following years by applying a nitrogen/sulfur blend of 41 percent N and 4 percent S. Base the rate on N recommendations for the cultivar grown. If there is an S deficiency, you'll see symptoms in young rice about 10 to 14 days after permanent flood establishment or during the late reproductive stages after prolonged flooding.

Sulfur Notes

What does sulfur do?

- Increases root growth
- Helps maintain dark green color
- Stimulates seed production
- Encourages plant growth

An S deficiency causes uniformly chlorotic (yellow), stunted rice plants. These symptoms look like those of N deficiency. However, unlike N, S does not move from older to younger plant parts. Sulfur deficiency on the younger growth may be the same shade of light green or yellow as is the older growth. Younger growth may also be lighter green with even lighter veins.

Micronutrients

Most of the soils suited to rice in the Mississippi Delta are high in micronutrients. Most soils range from pH 5 to 6.5. Few soils have native pH values higher than 7.5. Micronutrient deficiencies should be suspected only on light-textured, sandy loam, and silt loam soils. When the pH is higher than 7.5 on lighter-textured soils, a zinc deficiency may occur. Zinc deficiencies are especially common when soil has low organic matter, high phosphorus, and low zinc content. Symptoms of zinc deficiency in young seedling rice include the following:

- plants that appear bronzed and may have a very small, irregular, rusty pattern on the leaves
- leaves that are pale and drooping
- leaves that turn pale green on the bottom half 2 to 4 days after flooding
- leaves that become yellowish and start dying 3 to 7 days after flooding

The worst symptoms of deficiency appear in cold-water areas and where the flood is deepest. If you find a zinc deficiency before planting rice, add the recommended rate of zinc sulfate as determined by a soil test or add 35 pounds of zinc sulfate per acre before planting. If you see a zinc deficiency after rice has emerged, apply zinc chelate at the rate of 0.5 to 1 pound metallic zinc per acre as a foliar spray. Zinc chelate can be tank mixed with propanil for application if a propanil application for weed control is needed. If the symptoms occur after a permanent flood is established, drain the field. Apply zinc chelate at 1 pound per acre or 2 to 2.5 pounds per acre of the zinc complexes. Reflood the field after zinc application.

CHAPTER 7 Water Requirements and Management

Jim Thomas

Rice's in-season water demand and the flood weed control program make rice one of the highest water-use crops grown in Mississippi. Changes in technology have helped Mississippi rice growers use water more efficiently over the past several years. Many growers have been able to flood and flush fields with very little runoff. Several management tools can help you use resources better and still get high yields.

Water Requirements and Management

Rice production requires a good water source. Adequate floodwater provides a good environment for rice growth, helps control weeds, and stabilizes soil ammonium nitrogen. Water requirements vary depending on soil texture, number and length of irrigation ditches, soil moisture before flooding, perimeter levee and irrigation ditch seepage, evaporation, and transpiration by plants.

Generally, rice requires a water supply output of at least 15 to 20 gallons per minute per acre. Where there are multiple ditches or an extremely long ditch, the higher volume is better. Replace ditches with roll-out irrigation tubing whenever possible to decrease losses from evaporation and seepage from surface water ditch supplies. It is important to have enough water to establish a flood within 4 to 5 days. It is also important to be able to flush a field within 4 to 5 days. Once a flood is established, 5 to 8 gallons per minute per acre is usually enough to maintain the flood depending on how the flood is reestablished. An adequate water supply and timely flooding are necessary for maximum yields. Seeding methods may also determine the type of water management a grower uses.

Flooding Guide

The following information will help you determine the pumping time required to flood different-sized fields to 4 inches deep. The values listed are not absolute; they do not consider prior soil moisture conditions, soil type, levee leakage, field configuration, crop and weather demand, or other factors that may affect the water use in the field. When determining the amount of water used, remember that an acre-inch of water is 27,156 gallons and 450 gallons per minute is equivalent to 1 acre-inch per hour.

Daily water use is an average value for the whole season; peak water use is about 0.25-0.30 inches per day. Peak water use occurs during late vegetative and reproductive periods, and you may need to adjust pumping times to meet this higher-demand period.

Basis: 4"/A Flood
Total Seasonal Water Use: 23"-26"
Average Daily Water Use: 0.25"/Day

Well Size
Minimum - 8 gpm/A
Maximum - 30 gpm/A

Fuel Consumption per Acre-inch Well Capacity

$$\text{Acre-inches per hour} = \frac{\text{GPM}}{450}$$

Diesel
50' Lift-0.45 gallons of diesel/acre-inch
75' Lift - 0.70 gallons of diesel/acre-inch
100' Lift - 0.90 gallons of diesel/acre-inch

Electric
50' Lift - 6.4 KWH per hour/acre-inch
75' Lift - 9.6 KWH per hour/acre-inch
100' Lift - 12.8 KWH per hour/acre-inch

Divide well flow in gallons per minute by 450 to get the number of acre-inches per hour output (well flow in gpm/450=A-in/hour output). Here's an example of how to calculate the run time required for the well to replace a certain amount of water: A grower needs to replace 0.25 inches of water on a 75-acre field. This is a total of 18.75 inches, or 19 inches. A well that puts out 1500 gpm will pump 750/450=1.667 ac-in/hr. Nineteen inches to replace divided by the rate of 1.667 ac-in/hr equals 11.4 hours, or about 11 ½ hours, to replace the desired volume with a bit extra. These calculations are the basis for the guide on the following page.

Table 7.1. Pumping time to replace daily water use of 0.25" based on total pumping time required for initial flood of 4".

4" Flood	0.25" Daily Use	4" Flood	0.25" Daily Use
60	3.8	150	9.4
70	4.4	160	10.0
80	5.0	170	10.6
90	5.6	180	11.3
100	6.3	190	11.9
110	6.9	200	12.5
120	7.5	210	13.1
130	8.1	220	13.8
140	8.8	225	14.1

****Example: It takes between 8.1 to 8.8 hours of daily pumping to replace the 0.25" on the same basis that it takes between 130 to 140 hours to pump 4" on a field at a rate of 2000 gpm.**

Table 7.2. Total hours pumping for a 4-inch flood.

GALLONS PER MINUTE (GPM)

GPM	400	600	800	1000	1200	1400	1600	1800	2000*	2200	2400	2600	2800	3000	3500	4000	ACRES
	45																10
	90	60															20
	135	90	68	54													30
	180	120	90	72	60												40
	225	150	112	90	75	64	56										50
		180	135	108	90	77	68	60									60
		210	158	126	105	90	79	70	63	57							70
		240	180	144	120	103	90	80	72	65	60						80
			202	162	135	116	101	90	81	74	68	62					90
			225	180	150	128	112	100	90	82	75	69	64	60			100
				198	165	141	124	110	99	90	82	76	71	66			110
				216	180	154	135	120	108	98	90	83	77	72	62		120
				234	195	167	146	130	117	106	98	90	84	78	67	58	130
					210	180	158	140	126	114	105	97	90	84	72	63	140
					225	193	169	150	135	123	112	104	96	90	77	68	150*
						206	180	160	144	131	120	111	103	96	82	72	160
						218	191	170	153	139	128	118	109	102	87	77	170
						231	202	180	162	147	135	125	116	108	93	81	180
							214	190	171	155	142	132	122	114	98	86	190
							225	200	180	164	150	138	128	120	103	90	200
								210	189	172	158	145	135	126	108	95	210
								220	198	180	165	152	141	132	113	99	220
								230	207	188	172	159	148	138	118	104	230
									216	196	180	166	154	144	123	108	240
									225	204	188	173	161	150	128	113	250
										225	209	190	117	165	141	124	275
											225	208	193	180	154	135	300
												225	209	195	167	146	350
													225	210	180	158	350
														225	193	169	375
															206	180	400
															218	191	425
															231	191	450
																214	475
																225	500

HOURS

* Example: With 2000 gallons per minute on 150 acres, it takes a minimum of 135 hours to pump 4" on the whole field. Average daily water use is 0.25" per day.

When flooding a dry field, you probably need to pump an additional inch of water to take care of soil requirements and leaks in levees. This will mean increasing pumping by 25%.

Water-Use Conservation Checklist

Short-Term List

- Keep accurate water-use records about fields, including flush times, flood times, and replacement pumping times.
- Determine the flow rate of your wells by measurement, meter, or some other method. Use a flow meter on at least one well on the farm each year.
- Land-plane fields to help eliminate high and low spots, or use scrapers or ejector scrapers with lasers for minor cuts and fills on formed fields.
- If possible, divide fields that are 80 acres or larger into smaller fields with cross levees. Smaller fields are easier to manage.
- Make sure that all fields are accessible on all sides by three- or four-wheelers or truck to make flood management easier. This may require additional construction of farm turn rows or extra-wide outside levees.
- If you use a stale seedbed, drill into moist soil to get a stand with little or no flushing.
- Construct outside levees as soon as possible so they will have time to settle, which reduces seepage. Use tractor wheels to pack levees and help settle and seal them quicker.
- Construct permanent outside levees whenever possible.
- Pack all levees with dual wheels or levee packers during construction.
- Install metal or plastic gates in levees for better flood depth control.
- Use more than one gate per levee.
- Determine how long it takes to flush a field.
- Determine the approximate pumping time to establish a permanent flood.
- Know how many hours you should have to pump each day to maintain a permanent flood.
- Replace water lost to evaporation, leakage, or transpiration. Run engines at design speed for short intervals, which allows better fuel and pumping efficiency and reduces water costs.
- When possible, use surface water supplies. Mark the flood level in each bay while the rice is small so it can be identified easily and maintained better when the rice is larger.
- Ask aerial applicators to notify you of any water loss they see.
- When rain is likely, either turn wells off, do not pump, or allow enough free board in the field to use some extra rainfall without risking the flood depth.
- Check fields for water loss every day.
- Maintain a shallow flood, especially on semi-dwarf cultivars.
- Maintain a permanent flood no longer than 93 days.
- Turn well off several days before draining for harvest.

Long-Term List

- Have flow meters on every well.
- Level fields precisely for uniform grades and for more efficient production, especially on straight levees.
- Construct permanent outside levees around the field to be used as turn rows or roads and to decrease external levee seepage losses.
- Develop a long-term water management plan for your farm.
- Consider developing surface water supplies or reusing systems to help reduce pumping costs and save groundwater.
- Develop agreements with landlords on drainage, leveling, water delivery systems, and other water conservation measures.
- Improve water conservation systems with underground pipe, tail water recovery systems, multiple inlet/side inlet, or intermittent flooding.

"Cold Water" Rice

In many rice fields, cold-water areas occur and reduce the amount of rice produced in those areas. These areas are usually located where underground water is pumped directly into the upper bay of the field or around the gate area, where water flows into the field from flume ditches. Adding different types of fertilizers, such as ammonium sulfate, will not eliminate these problem areas. These three practices help reduce rice injury caused by cold water:

- Pump only at night, if possible, so the sun can warm the water during the day.
- Install overflows that are at least 15 feet long in the levees of the upper first three bays where the water is pumped.
- Use multiple or side inlet irrigation.

Install large overflows after a permanent flood has been established to make it easier to determine where the flood level needs to be on the levee. Remove the soil from the top of the levee down to the permanent flood line and install the plastic overflow. This practice is probably best used in combination with night pumping. If you only install overflows, the cold-water area will get bigger. However, the rice will be less damaged because the cold water is spread over a larger area than if it were confined mostly to one or two bay areas.

Side inlet irrigation has worked well for several Delta area rice farmers. Pump water through roll-out pipe laid across one side of the field. The pipe in each bay should have enough holes to handle the volume of water the well pumps and to help water flow into each bay. The whole field is brought to flood depth at the same time, and each bay is filled equally. When one is full, the whole field is flooded. This practice reduces the cold-water area significantly. To further reduce the effect of cold water, you should add water at night.

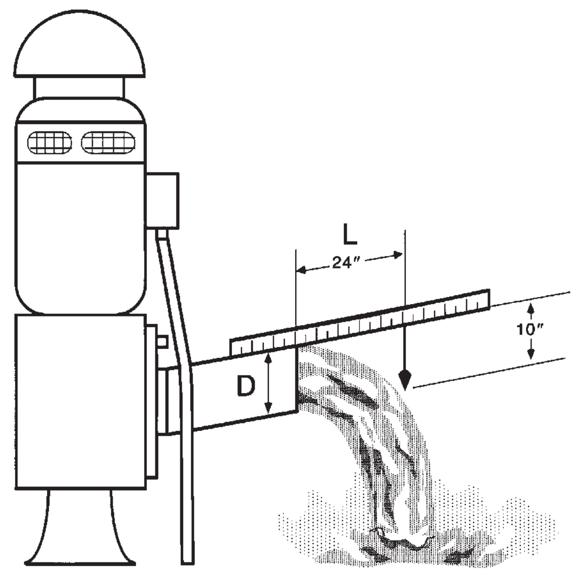
Water Management Notes

- Do not maintain a flood deeper than 6 inches, or tillering will be inhibited.
- Flush the field when these conditions exist: there is not adequate shallow moisture for proper seed germination, crusting occurs, or young seedlings become drought stressed.
- Maintain a continuous flood unless you need to drain for straighthead.
- Remember that the soil pH approaches neutral when soils are flooded.

How To Calculate for Pump Flow and Pumping Efficiency

Measuring Procedure

Extend yardstick parallel with discharge pipe until plumb bob barely touches the water stream. Measure length (L) and pipe inside diameter (D).



Formula

Gallons per minute = the inside diameter squared x the length in inches.

$$GPM = D^2 \times L$$

Example

Diameter of discharge pipe - 10" (D)

Length of discharge - 24" (L)

$$GPM = 10 \times 10 \times 24$$
$$GPM = 2,400$$

Note

Discharge pipe must be full for this method to be accurate. See following table for flow rates at different discharge lengths and pipe diameters.

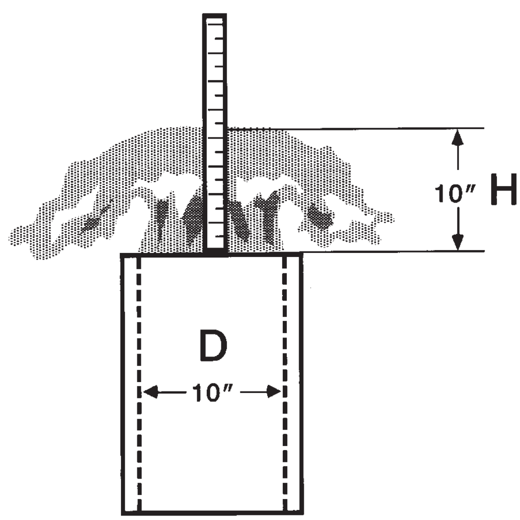
Table 7.3. Horizontal pipe flow rates.					
Length (L)	Inside diameter of pipe (D) - Inches				
Inches	6"	8"	10"	12"	14"
	GPM	GPM	GPM	GPM	GPM
6"	216	384	600	864	1176
8"	288	512	800	1152	1568
10"	360	640	1000	1440	1960
12"	432	768	1200	1728	2352
14"	504	896	1400	2016	2744
16"	576	1024	1600	2304	3136
18"	648	1152	1800	2592	3528
20"	720	1280	2000	2880	3920
22"	792	1408	2200	3168	4312
24"	864	1536	2400	3456	4704
26"	936	1664	2600	3744	5096
28"	1008	1792	2800	4032	5488
30"	1080	1920	3000	4320	5880
32"	1152	2048	3200	4608	6272
34"	1224	2176	3400	4896	6664
36"	1296	2304	3600	5184	7056

Vertical Flow

Measuring Device
Yardstick

Measuring Procedure
Measure the inside diameter (D) of the pipe. Measure discharge height (H) of water stream. See figure.

Formula
Gallons/minute = 5.67 x the square root of the height x the diameter squared.



Example
Discharge pipe - 10" (D)
Discharge height - 10" (H)

$$GPM = 5.67 \times \sqrt{10} \times 102$$
$$GPM = 5.67 \times 3.1623 \times 100$$
$$GPM = 1793$$

Note
See following table for flow rates at different water heights and pipe diameters.

Table 7.4. Vertical pipe flow rates.

Height (L)	Inside diameter of pipe (D)-Inches				
Inches	6"	8"	10"	12"	14"
	GPM	GPM	GPM	GPM	GPM
2"	289	513	802	1155	1572
4"	408	726	1134	1633	2223
6"	500	889	1389	2000	2722
8"	577	1026	1604	2309	3143
10"	645	1148	1793	2582	3514
12"	707	1257	1964	2828	3850
14"	764	1358	2122	3055	4158
16"	816	1452	2268	3266	4445
18"	866	1540	2406	3464	4715
20"	913	1623	2536	3651	4970
22"	957	1702	2659	3830	5213
24"	1000	1778	2778	4000	5444

Soil Considerations

Because rice is a flooded crop, you should avoid planting it on high intake rate soils or high percolation rate soils. Clay soils, clay pan soils, or fragipan soils are usually better suited for rice production. Silt loam or sand soils without a pan or clay subsoil are often very difficult to keep flooded; they lose water at a high rate and tend to leach fertilizers below the root zone, especially nitrogen fertilizers. Some clay loams and sandy clay loams can maintain a flood if properly managed. Use your county's soil survey to help you determine how suitable your soil is for flood irrigation of rice. Table 7.2 shows the pumping time needed to flood a specific acreage at a certain well flow in gallons per minute (gpm) to a 4- inch depth. Pumping time is based on no soil wetting needs or percolation. If the soil is dry, allow for the amount of water needed to refill the profile to saturation plus the flood depth.

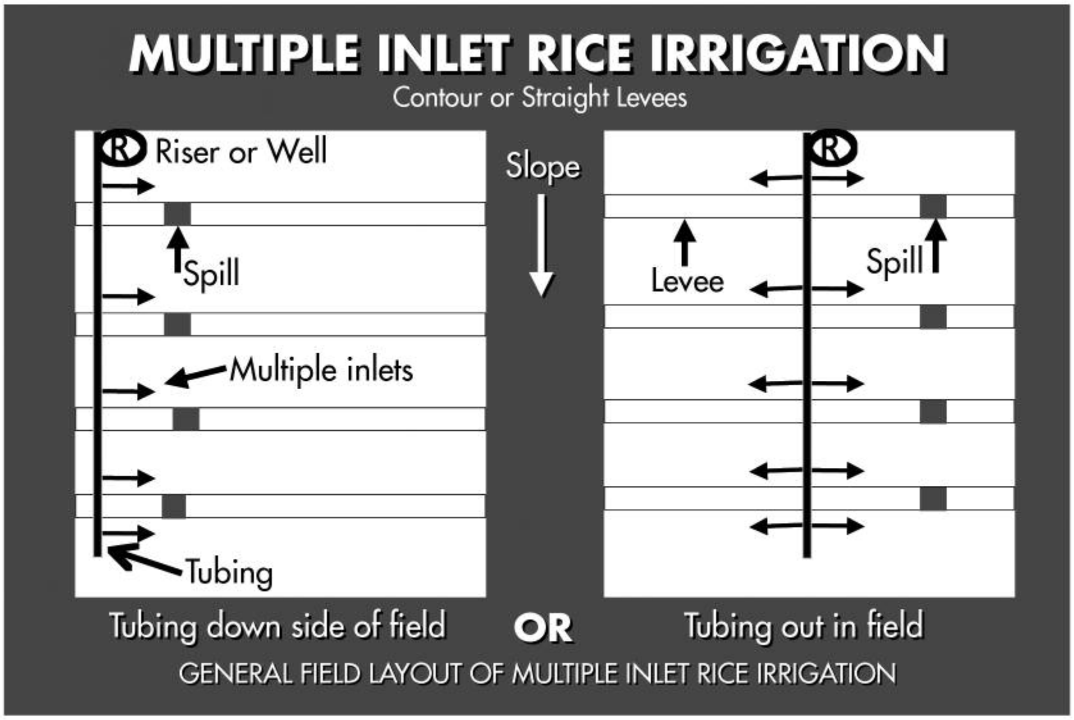


Figure 8.1.

Multiple Inlet Irrigation

Introduction

Most of the rice-growing areas in Arkansas and Mississippi have abundant water supplies. However, the water from underground aquifers won't last forever, as some rice producers are discovering. Groundwater monitoring indicates that the water table is declining in some areas of the Delta. Mississippi reports show that during the past decade, the water table has dropped an average of 10 feet. Six Grand Prairie counties in Arkansas are considered critical groundwater areas because of continued decline in the groundwater. Multiple Inlet (MI) irrigation in rice can conserve water, energy, and labor, which can help protect natural resources and increase profit.

Multiple inlet irrigation means that areas between the levees are irrigated individually and at the same time. With MI, less water has to flow from one levee to another, which can reduce the amount of water leaving the field. Multiple inlet can also flood the field quickly, which helps activate herbicides, increases fertilizer efficiency, and protects natural resources. Pumping cost with MI irrigation is usually less than with most conventional flood irrigation. It can reduce cold-water areas, increasing yield uniformity and possibly the total yield.
Several studies on multiple inlet irrigation for rice have shown water savings of up to 50 percent and average savings of about 25 percent.

Multiple Inlet Irrigation Installation

Figure 8.1 shows the general MI irrigation layouts for each levee to receive water at about the same rate so the whole field floods uniformly. Irrigation tubing can be laid on the edge of an elevated turnrow or pad beside a field. Place tubing in a 2- to 4-inch deep trench to keep it from twisting or rolling. You'll need to hold the water in the pipe at the upper end of the field so all the water does not flow to the low end of the tubing. You can stop the water by wrapping something around the tubing, placing barrels under the tubing, shoveling up dirt mounds under the tubing, or elevating the end of the tubing with a pipe. Use one of these methods or any other way to restrict the water. When restrictions are in place, let some water flow

Tubing in field

Culvert pipe under tubing

Twisted tubing

PVC pipe in tubing

Choke rope on tubing

out of the elevated pipe into the lower levee areas to avoid bursting the tubing. Use the heavier grade (9-10 mil) tubing for MI irrigation in rice.

You can lay tubing in a trench at the base of the pad, in the turnrow, or in the trench of the levee around the field. Because the tubing crosses the levees, the water cannot flow directly to the low end of the field. The tubing should cross each levee at a right angle so it won't twist or roll as it goes over the levee. If the levee trench is deep where the tubing crosses, shovel a small dirt ramp across it to give a smoother flow transition over the levee. Make a place for the tubing with a 1- to 2-inch depression on the top of levees that are settled and firm. This is not necessary on soft or fresh levees because the weight of the tubing and water will make a depression. In some cases the levee settles too much under the tubing's weight, causing water to wash the levee out under the tubing. Place a levee tarp or scrap piece of tubing on levee crossings where this may be a problem.

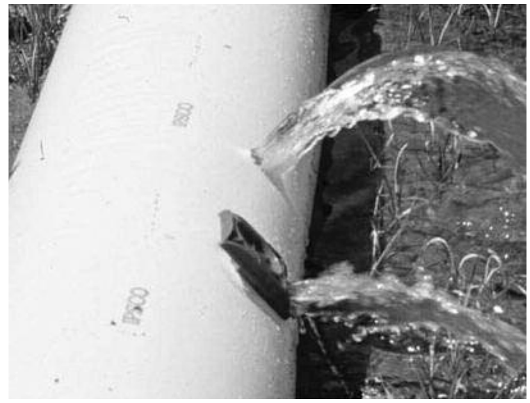
You can lay out the tubing in trenches in the field or even through the middle of the field (Figure 8.1). Place a 4- to 6-inch-diameter pipe under the irrigation tubing where it crosses the low side of the levee interval in the trench on the upper side of the lower levee. The pipe serves as a culvert, allowing water to flow under the tubing and distribute evenly on both sides of the field. Some growers install levee spills on both sides of the tubing. Levee spills can help keep rain from washing out levees if the pipes under the tubing do not allow the water to flow quickly enough. Tubing placed out in the field is more likely to float and move with the wind, which can make it twist and roll. A practical way to prevent this problem is to drive .75 - to 1-inch-diameter PVC pipe through the tubing. Do this when water is in the tubing and it is settled in place. Punch a 1.2-inch diameter hole in the top of the tubing. Push the PVC pipe through this hole and hammer it down once it rests against the bottom of the tubing. The PVC pipe should be placed about halfway between levees. Tubing that runs across big flat areas between levees may require two PVC pipes, spaced out evenly between the levees. Once the rice gets tall and thick, the tubing is much less likely to move.

Characteristics such as field size and slope, levee pattern, water location, flow, and grower preference determine how the tubing is laid out. It may not be practical to run the tubing to the last few levees if they account for only a small acreage and crossing them would require a lot of tubing. In this situation, you can discharge extra water from the end of the tubing so it can flow through the levee spills and into the last few levees. Irrigation tubing is usually the delivery system of choice, but you can use gated aluminum or PVC pipe if it can be laid out alongside a field. Running the tubing down the side of the field and straight over the levees works best in most cases.

Controlling the Flow

It is important the tubing is sized properly so it does not fail because it is too small or stay too flat because it is too big. Here are recommended flow ranges for the tubing:

12 inch – less than 1,200 gpm
15 inch – 1,200 to 2,200 gpm
18 inch – greater than 2,200 gpm



Blue gate

Sometimes it's wise to size down to the next smaller size tubing after covering a significant amount of the field. For example, you may start with 15-inch tubing for a 2,000 gpm flow but go to 12-inch after half of the field has been covered and the flow is probably 1,000 gpm or less. When the flow in the tubing doesn't keep the tube rounded, gates and holes may not flow fully, and the tubing may flap enough to cause it to tear. Flapping is more common on steep fields and on the downslope side of levees. Proper-sized tubing can help reduce this problem, but you may have to use rope or strapping to restrict the tubing below the flapping portion.

Place adjustable 2.5-inch diameter slide gates, holes, or both in the tubing. Gates and holes are water inlets to each levee that the tubing crosses. Place gates or holes near the top of the tubing at the 11 or 1 o'clock position. They can be placed anywhere between the levees. When gates or holes are close to the upper levee, the tubing holds more water when not irrigating and is less likely to float or move. The holes or gates are adjusted when flooding the field so that each levee floods up at about the same rate. Most growers find that after the initial adjustments, they don't have to spend as much time with the water management as they do with most fields that are flooded conventionally.

Air pocket in tubing

Additional adjustments during the season may be necessary if the flow to the field changes significantly, which is common in pipeline systems that have several wells and multiple pumping outlets. Be sure to punch small relief holes in air pockets that form in the tubing. Air pockets restrict the water flow through the tubing and can become "hot spots" where the tubing may stretch, thin, or rupture.

Calculating the Irrigation Plan

To use multiple inlet irrigation, you must know the total acreage, the pumping capacity in gallons per minute, and the approximate number of acres in each levee. You can use estimates to determine basic layout, but more accurate information makes the system easier to set up. Setting up MI irrigation requires extra time and labor early in the production season. The labor for the rest of the season is usually about 30 percent less than is required with conventional flood.

To set up MI irrigation, divide the pumping capacity by the field acreage to get a ratio in gallons per minute per acre (gpm/A). Then multiply this ratio by each levee's acreage to get the gpm needed in each levee so the water is proportioned evenly across the entire field.

For example, an 80-acre field has 7 levee areas and a well that pumps 2,000 gpm. Dividing 2,000 gpm by 80 acres gives a ratio of 25 gpm/A. The first 4 levees are about 13 acres each, and the last 3 are about 10 acres each. Therefore, each of the first 4 levees needs 325 gpm (13 A x 25 gpm/A) and each of the next 3 need 250 gpm (10A x 25 gpm/A). The 2.5-inch adjustable slide gates deliver about 75 gpm when fully open. A possibility for the first 4 levees is to punch four gate holes in the tubing to get 300 gpm (4 gates x 75 gpm/gate) and then install one gate to regulate the remaining 25 gpm that is needed. Each of the last three levees could have three gate holes punched for 225 gpm (3 gates x 75 gpm/gate) and 1 gate installed to adjust for the remaining 25 gpm. Growers who have a lot of experience with punching the smaller holes for row watering may be able to determine the size and number of holes to punch for each levee and plug holes to reduce the flow.

Regulating flood depth is typically easier with multiple inlet irrigation, but water may still flow through some of the levee spills. Set levee spills 1 to 2 inches higher than the desired flood depth, leaving room for rain to be captured on the field instead of lost as runoff. MI irrigation can also reduce the risk of levees washing out from overpumping the top levees or getting rain when the field already has a deep flood. You can add extra water directly to any levee area without routing it through all the levees above it, as you would have to do with conventional flood irrigation. This is helpful when water needs vary because of soil type, muskrat holes, or other factors. If a field has to be drained for straighthead control, MI irrigation can reestablish the flood quicker than a conventional flood system could.

Multiple Inlet Irrigation Advantages

Growers using multiple inlet irrigation report that it provides other water management advantages, including these:

- Getting and keeping water on the bottom of certain fields
- Sharing water with other irrigated crops
- Maintaining shallower flood early to avoid stretching rice
- Recovering faster from well shutdowns or delays in starting pumping
- Reducing scum and algae buildup at levee spills
- Managing the irrigation water on fields with steep slopes more efficiently

Growers and irrigation water managers often question the effectiveness of MI irrigation for rice because it is so different from what they have always done. However, almost all who try multiple inlet irrigation end up using it on some or most of their rice fields. Multiple inlet irrigation alone will not totally fix the long-term problem of declining groundwater resources. Efforts to develop surface water sources and other irrigation methods that can save groundwater must be continued. However, MI irrigation can help address the situation today while other long-term solutions are being developed.

CHAPTER 8
Rice Weed Control

Nathan Buehring and Jason Bond

Weeds are one of the most limiting factors in rice production in Mississippi. Weeds reduce rice yields by competing for water, nutrients, space, and sunlight. Weeds can reduce harvesting efficiency and rice quality and increase problems with drying rice. Mississippi rice growers spend about 7.5 to 15 million dollars on weed control each year.

Several weeds are found in rice throughout Mississippi. Table 8.1 lists the top ten most common and troublesome weeds in Mississippi rice production.

Table 8.1. Ten Most Common and Troublesome Weeds in Mississippi

	Common	Troublesome
1	Barnyardgrass	Barnyardgrass
2	Hemp Sesbania	Palmleaf Morningglory
3	Pitted Morningglory	Pitted Morningglory
4	Palmleaf Morningglory	Red Rice
5	Red Rice	Amazon Sprangletop
6	Ducksalad	Ducksalad
7	Redstem	Redstem
8	Amazon Sprangletop	Yellow Nutsedge
9	Broadleaf Signalgrass	Broadleaf Signalgrass
10	Yellow Nutsedge	Hemp Sesbania

In recent years, other weeds, such as Texasweed, smartweed, and spreading dayflower, have become increasingly problematic.

You must understand weed competition to get maximum yields and control weeds effectively. Table 8.2 lists the critical weed density thresholds for Mississippi rice production. These suggested thresholds show that even light populations of weeds can really affect rice yields. Most grass weeds are competitive with rice early in the growing season. Red rice and other broadleaf weeds are more competitive late in the growing season.

Duration of weed competition is another factor to consider when determining how to control weeds. Research has shown that 17 days of barnyardgrass competition reduced Newbonnet yields by 10 percent. The yield reductions were almost 20 percent for Lemont, a semidwarf cultivar. This and other data has shown that semidwarf cultivars compete less with rice weeds than taller cultivars do. Yield reductions due to weed competition can be higher with semidwarf cultivars.

Crop Rotation

Crop rotation is a good agronomic decision and a good weed management decision. Continuous rice can lead to problems with red rice and aquatic weeds. If red rice is a problem, a 2-year soybean and 1-year rice rotation will help control weeds. Rotating another crop such as soybean, corn, or cotton every other year can improve aquatic weed problems.

Cultural Weed Control

Around the 5-leaf stage, rice is typically flooded for weed control. Using an herbicide and flooding at the proper time and depth is critical for good weed control. Proper water management includes land leveling to remove potholes and ridges, accurate levee surveying to prevent deep-water areas, and timely flooding after the last preflood herbicide application. If the flood is not maintained, weeds can emerge at any time and cause problems. Any low areas or ridges in fields will also increase weed control problems. Ridges prevent uniform

Table 8.2. Suggested Critical Density Thresholds for Selected Weeds

Weed Species	Plants/ft2
Red Rice	0.1 - 0.3
Barnyardgrass	0.5 - 1.0
Broadleaf Signalgrass	1.9 - 3.7
Bearded Sprangletop	1.4 - 2.8
Hemp Sesbania	0.1 - 0.2
Northern Jointvetch	0.3 - 0.6

Each density indicates the need for a herbicide application. Source: R.J. Smith. 1988. *Weed Technol.* 2:232-241.

flooding after herbicide application and allow weeds to reinfest. Low areas with standing water prevent maximum herbicide contact with weeds.

A uniform rice stand is necessary to control many aquatic weeds. A uniform stand of 15 to 20 rice plants per square foot can compete with ducksalad and other aquatics and keep these weeds from becoming a problem. To get a uniform stand of rice, level fields to allow proper flooding and draining.

Reduced Tillage and Stale Seedbed Systems

Reduced tillage and stale seedbed systems are becoming more common in Mississippi rice production. Using these systems typically requires a burndown herbicide application. To reduce the amount of vegetation at planting, make a timely burndown application around February or March. Herbicides labeled for preplant burndown use in rice include Gramoxone Inteon, Glyphosate, 2,4-D, FirstShot, and Valor. When selecting a burndown herbicide, be sure to consider weed control spectrum, weed size, and preplant interval.

Most burndown applications in rice begin with a base application of either glyphosate or Gramoxone Inteon. Glyphosate is generally slower in activity than Gramoxone Inteon is. FirstShot, Valor, and 2,4-D are tank mixed with either glyphosate or Gramoxone Inteon to increase broadleaf weed control. Valor provides residual weed control. Herbicide selection and rate depend on weed size. These herbicides generally perform better on young, actively growing weeds. Table 8.4 lists expected weed control level for each herbicide.

Table 8.3. Preplant interval for burndown herbicides in dry-seeded rice production.

Herbicide	Preplant Interval (days)
Glyphosate	Before rice emergence
Gramoxone Inteon	Before rice emergence
2,4-D	28
FirstShot	0
Valor (1 to 2 oz/A)	30[a]

[a] At least one inch of rainfall/irrigation must occur between application and planting, or crop injury may result.

Consider the preplant interval (time between herbicide application and planting) when making a burndown herbicide application. Table 8.3 lists the preplant intervals for burndown herbicides in dry-seeded rice production. Planting before the interval expires can injure rice.

Herbicide Options

Rice producers may select from many different herbicides and tank-mix options. The best option for one producer may not be the best for another producer. The right choice depends on the weeds in the field. Timing an herbicide application poorly could compromise weed control. Early-season weed control is necessary for good weed control and to prevent weed competition from robbing yield. Before using any herbicide, always read the label and follow its instructions.

Table 8.5 shows weed control ratings for each herbicide on important rice weeds. These are average expected performance ratings. Poor environmental conditions can make herbicides less effective. Table 8.6 lists several different herbicide options that could be used for weed control in rice.

Table 8.4. Winter weed response ratings to herbicides.	Annual Bluegrass	Ryegrass	Bittercress	Buttercup	Carolina Geranium	Chickweed	Cutleaf Eveningprimrose	Groundsel	Hebit	Shepherdpurse	Wild Lettuce	Virginia Pepperweed	Vetch	Little Barley/Carolina Foxtail	Glyphosate-Resistant Horseweed	Curly Dock	Smartweed
Glyphosate	**10**	8	**10**	**9**	7	**10**	6	**9**	7	**10**	8	8	5	**10**	2	7	7
+ Weedar 64 (2,4-D)	**10**	7	**10**	**10**	**9**	**10**	**10**	**9**	**9**	**10**	**10**	**9**	**10**	**10**	**9**	**9**	8
+ FirstShot	**10**	7	**10**	**10**	**9**	**10**	7	**9**	**9**	**10**	**9**	**10**	5	**10**	5	**10**	**10**
+ Valor	**10**	8	**10**	**10**	8	**10**	**9**	**9**	**9**	**9**	-	-	-	**10**	8[1]	-	6
Gramaxone Inteon	**10**	7	**9**	**10**	**9**	**10**	7	7	8	**9**	7	7	8	8	5	6	6
+ Weedar 64 (2,4-D)	**10**	7	**10**	**10**	**9**	**10**	**10**	**9**	**9**	**9**	-	8	**9**	**9**	**9**	**9**	8
+ FirstShot	**10**	7	**10**	**10**	**10**	**10**	7	**9**	**9**	**10**	-	5	5	7	5	**9**	**10**
+ Valor	**10**	7	**9**	**10**	**9**	**10**	**9**	**9**	**9**	**9**	-	-	-	-	8[1]	-	6

[1] **Residual control only.**

Table 8.5. Weed Response Ratings for Rice Herbicides[a].

	Amazon Sprangletop	Ammania (Redstem)	Barnyardgrass	Bearded Sprangletop	Broadleaf Signalgrass	Cocklebur	Crabgrass	Dayflower	Ducksalad	Eclipta	Fall Panicum	Flatsedges	Gooseweed	Hemp Sesbania	Morningglory	Northern Jointvetch	Nutsedge	Purslane	Smartweed	Spikerush	Water Hyssop	Texasweed (2-3 leaf)	Johnsongrass (Rhizome)	Red Rice
Preemergence																								
Command pre/delayed pre	**9**	0	**9**	**9**	**8**	2	**9**	3	3	3	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0
Facet pre/delayed pre	0	3	**9**	0	**9**	4	**9**	5	3	**8**	**9**	5	3	6	7	7	0	-	0	-	6	-	-	0
Bolero delayed pre	7	7	7	7	5	4	7	**8**	7	**8**	7	7	6	5	5	5	4	-	5	7	7	3	-	0
Prowl delayed pre	6	3	**8**	6	6	0	**8**	0	z	0	7	0	0	0	0	0	0	**8**	0	0	0	0	-	0
Facet + Bolero delayed pre	**8**	6	**9**	**8**	**9**	4	**9**	7	7	**9**	**9**	**8**	5	**8**	**8**	**8**	0	-	5	7	6	-	-	0
Facet + Prowl delayed pre	7	3	**9**	7	**9**	0	**9**	5	3	**8**	**9**	5	3	7	**8**	7	0	**8**	0	-	6	-	-	0
Early Postemergence																								
Newpath (2 applications)	6	**8**	**9**	**8**	**9**	**9**	**9**	5	5	0	**9**	**9**	5	0	7	0	**8**	0	**9**	**9**	0	-	0	**9**
Propanil early post	5	6	**9**	4	**9**	5	7	5	7	**8**	**9**	**9**	5	**9**	4	**9**	4	7	6	**9**	**8**	7	-	0
Facet early post	0	3	**9**	0	**9**	4	7	3	3	**9**	6	5	3	**8**	**8**	**8**	0	-	0	-	3	3	-	0
Propanil + Facet early post	5	6	**9**	4	**9**	5	7	5	6	**9**	**9**	**9**	5	**9**	**8**	**9**	5	7	6	**9**	**8**	7	-	0
Clincher early post	**8**	0	**8**	**9**	**9**	0	6	0	0	0	**8**	0	0	0	0	0	0	0	0	0	0	0	4	0
Ricestar early post	**8**	0	**8**	**9**	**9**	0	**8**	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	7	0
Grasp	0	7	**8**	0	0	**9**	0	7	**8**	7	0	**9**	-	**8**	5	7	6	-	7	**8**	**8**	6	-	0
Regiment late post	0	6	**9**	0	0	-	0	**9**	**9**	7	0	**8**	0	**8**	5	7	0	0	**8**	-	6	6	**8**	0
Londax late post	0	**9**	0	0	0	0	0	**8**	**9**	**8**	0	**8**	**9**	6	5	6	6	-	6	**8**	**9**	-	-	0
Duet prior to flood	5	**9**	**9**	4	**9**	5	7	**8**	**9**	**8**	**9**	**9**	**9**	**9**	**8**	**9**	**8**	7	**8**	**9**	**9**	**8**	-	0
Permit	0	0	0	0	0	**9**	0	**8**	3	0	0	**8**	-	**8**	4	3	**9**	-	4	**9**	-	4	-	0
Basagran early	0	**8**	0	0	0	**9**	0	**9**	6	**8**	0	**8**	7	3	3[b]	-	7	-	7	**8**	**8**	-	-	0
Aim	0	6	0	0	0	**9**	0	7	5	7	0	0	-	**9**	**9**	6	0	**9**	**9**	0	7	**8**	-	0
Grandstand + Permit	0	6	0	0	0	**9**	0	**9**	4	5	0	**8**	-	**9**	**9**	**9**	**9**	-	7	-	-	**8**	0	0
Midseason																								
Ultra Blazer midseason	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**	3	-	0	-	0	0	0	4	-	0
2,4-D midseason	0	**9**	0	0	0	**9**	0	**9**	**9**	**9**	0	**8**	6	**9**	**9**	5	5	-	6	**8**	**9**	-	0	0

[a]Control expected under optimum conditions. Mississippi State University does not guarantee these estimates because many factors cause herbicide performance to vary. Rating Scale: 0 - 3 = none to slight, 4 - 6 = fair, 7 - 8 = good, 9 - 10 = excellent.

[b]8 for palmleaf morningglory.

Table 8.6. Herbicides, rates, and application methods in Mississippi rice production.			
Herbicide	**Rate**	**Weeds Controlled**	**Comments**
Preplant (before rice is seeded)			
Glyphosate	1 pt - 1.5 qt/A (of a 3 lb AE/gal formulation)	Annual and perennial grasses and broadleaf weeds.	Apply to actively growing weeds shorter than 6 inches. Higher rates are necessary for larger perennial weeds.
Gramaxone Inteon	2.0 - 4.0 pt/A	Annual and perennial grasses and broadleaf weeds.1-3 inches: 2.0-2.5 pt 3-6 inches: 2.5-3.0 pt > 6 inches: 3.0-4.0 pt	Add nonionic surfactant at 0.25% v/v
Weedar 64 (2,4-D)	1 - 2 pt/A	Annual and perennial broadleaf weeds.	Apply at least 28 days before planting. Do not apply by air after March 31. Apply no more than 2.5 pt/A per growing season.
FirstShot	0.5 - 0.6 oz/A	Winter annual and some perennial broadleaf weeds.	Apply to actively growing weeds. Product has a 0-day plant back restriction.
Valor	2 oz/A	Enhanced control of primrose, henbit, Carolina geranium, and wild mustard when applied with either glyphosate, Gramoxone Inteon or 2,4-D.	Apply at least 30 days before planting. 2 oz/A provides residual control of henbit, chickweed, and dandelion.
Newpath	4 - 6 fl oz/A	Red rice and most annual grasses.	Incorporate for best results. Must be followed by 1 application of Newpath at 4-6 fl oz/A postemergence. Can only use 4 fl oz/A on Clearfield hybrids.
Preemergence (before rice emerges)			
Command 3ME	1.125 - 1.6 pt/A	Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, and sprangletop sp.	If there's no significant rain soon after application, flush the field to activate the herbicide. Do not use on coarse, light, sandy soils. Do not apply to recently precision-graded fields.
Facet 75DF	0.33 lb/A (Course soil, sand) 0.5 lb/A (Medium soil, loam) 0.67 lb/A (Fine soil, clay)	Annual grasses except for sprangletop sp. Controls morning glory, sesbania, and eclipta.	If there's no significant rain soon after application, flush the field to activate the herbicide. Do not apply to recently precision-graded fields.
Command 3ME + Facet 75DF	1.125 - 1.6 pt/A + 0.33 - 0.67 lb/A	Annual grasses including sprangletop. Controls morning glory, sesbania, and eclipta.	If there's no significant rain soon after application, flush the field to activate the herbicide. Do not apply to recently precision-graded fields.

Herbicide	Rate	Weeds Controlled	Comments
Delayed PRE (After rice seed has imbibed water for germination)			
Facet 75DF	0.33 lb/A (Course soil, sand) 0.5 lb/A (Medium soil, loam) 0.67 lb/A (Fine soil, clay)	Annual grasses except for sprangletop sp. Controls morning glory, sesbania, and eclipta	If there's no significant rain soon after application, flush the field to activate the herbicide. Do not apply to recently precision-graded fields.
Bolero	4 pt/A	Barnyardgrass, sprangletop, and various aquatic weeds.	If there's no significant rain soon after application, flush the field to activate the herbicide. Seed must have soaked up water for germination before application.
Prowl H20 Pendimax	1.5 - 2.0 pt/A 1.8 - 2.4 pt/A	Annual grasses.	If there's no significant rain soon after application, flush the field to activate the herbicide. Seed must have soaked up water for germination before application.
Facet 75DF + Bolero	0.33 - 0.67 lb/A + 3 - 4 pt/A	Annual grasses, including sprangletop. Also controls morning glory, sesbania, and eclipta.	If there's no significant rain soon after application, flush the field to activate the herbicide.
Facet 75DF + Prowl H20, or Pendimax	0.33 - 0.67 lb/A 1.5 - 2.0 pt/A, or 1.8 - 2.4 pt/A	Annual grasses, including sprangletop. Also controls morning glory, sesbania, and eclipta.	If there's no significant rain soon after application, flush the field to activate the herbicide.
Postemergence (Contact)			
Propanil	3 - 4 qt/A of 4 lb/gal formulation	Many common grass and broadleaf weeds	Apply when temperature highs are between 75 and 95 °F. Do not apply a carbamate or organophosphate insecticide within 14 days before or after a propanil application. Do not apply to drought-stressed weeds.
Duet (Propanil + Londax)	3 - 4 qt/A	Annual grasses, broadleafs, and sedges	See above comments.
Clincher SF	13.5 - 15 fl oz/A	Annual grass control only	Flush before the application if adequate moisture is not present. Add a nonphytotoxic crop oil at 1 qt/A. Do not apply by air within 2 miles downwind or 4 miles upwind of peaches or nectarines.
Ricestar HT	17 fl oz/A	Annual grass control only	Flush before the application if adequate moisture is not present. Do not apply within 48 hours of an application of methyl parathion.
Regiment 80SP	0.4 - 0.67 oz/A	Barnyardgrass, johnsongrass, hemp sesbania, northern jointvetch, ducksalad, and smartweed	Use an adjuvant approved by Valent. Avoid movement to soybean.
Permit 75DF	0.67 - 1.33 oz/A	Annual sedge, yellow and purple nutsedge	Add nonionic surfactant at 0.25 to 0.5% v/v. Add Propanil to increase grass and broadleaf control.

Herbicide	Rate	Weeds Controlled	Comments
Londax 60DF	1 - 1.6 oz/A	Aquatic weeds and yellow nutsedge	Add a crop oil concentrate at 1% v/v or nonionic surfactant at 0.25% v/v. Add Propanil to increase grass and broadleaf control.
Grasp 2SL	2 - 2.8 oz/A	Barnyardgrass, hemp sesbania, ducksalad, and annual sedges	Add crop oil concentrate at 1% v/v. Avoid using on soils with pH of more than 7.8.
Basagran	0.75 - 1 qt/A	Dayflower, smartweed, redstem, cocklebur, and yellow nutsedge	Add crop oil concentrate at 1.25% v/v. Add Propanil to increase grass and broadleaf control.
Ultra Blazer	0.5 - 1.0 pt/A	Hemp sesbania	Add nonionic surfactant at 0.25% v/v. Add Propanil to increase grass and broadleaf control.
Storm	1.5 pt/A	Cocklebur, dayflower, hemp sesbania, redstem, smartweed, and annual sedge	Add nonionic surfactant at 0.25% v/v. Add Propanil to increase grass and broadleaf control.
Grandstand	0.67 - 1.0 pt/A	Hemp sesbania, northern jointvetch, morning glory, redstem, and cocklebur	Add nonionic surfactant at 0.25 to 0.5 % v/v. Do not apply a flood within 72 hours. Do not apply to recently precision graded fields. Add Propanil to increase grass and broadleaf control.
Aim 2EC	1.6 - 3.2 fl oz/A	Cocklebur, hemp sesbania, northern jointvetch, smartweed, and morningglory	Add nonionic surfactant at 0.25 % v/v or crop oil concentrate at 1% v/v. Do not apply after internode elongation. Add Propanil to increase grass and broadleaf control.
Postemergence (Contact) plus Residual			
Facet 75DF	0.33 - 0.67 lb/A	Annual grasses except for sprangletop sp. Controls morning glory, sesbania, and eclipta	Add crop oil concentrate at 1 qt/A. If there's no significant rain soon after application, flush the field to activate the herbicide. Do not apply to recently precision-graded fields.
Propanil + Facet 75DF	3 - 4 qt/A + 0.33 - 0.67 lb/A	Barnyardgrass, broadleaf signalgrass, morning glory, hemp sesbania, northern jointvetch, and annual sedge	Apply to actively growing weeds. Flushing may be required for activation.
Propanil + Prowl H2O, or Pendimax	3 - 4 qt/A + 1.5 - 2.0 pt/A, or 1.8 - 2.4 pt/A	Postemergence control of common grass and broadleaf weeds. Preemergence control of barnyardgrass, broadleaf signalgrass, crabgrass, and sprangletop	Apply when soil is moist. Do not make more than one Prowl or Pendimax application in a growing season. Flushing may be required for activation.
Propanil + Bolero	3 - 4 qt/A + 3 - 4 pt/A	Postemergence control of common grass and broadleaf weeds. Preemergence control of barnyardgrass, sprangletop, and various aquatic weeds.	Apply under moist soil conditions. Do not apply to stressed rice. Flushing may be required for activation.
Propanil + Command 3ME	3 - 4 qt/A +1.125 - 1.6 pt/A	Postemergence control of common grass and broadleaf weeds. Preemergence control of barnyardgrass, broadleaf signalgrass, crabgrass, and sprangletop	Apply under moist soil conditions. Flushing may be required for activation.

Herbicide	Rate	Weeds Controlled	Comments
Clincher SF or Ricestar HT + Command 3ME	13.5 -1 5 fl oz/A or 17 fl oz/A + 1.125 - 1.6 pt/A	Postemergence control of annual grasses. Preemergence control of annual grasses.	Apply under moist soil conditions. Flushing may be required for activation. Add a nonphytotoxic crop oil at 1 qt/A if Clincher SF is used.
Newpath	4 - 6 fl oz/A	Red rice and most annual grasses.	Apply to Clearfield rice cultivars. Only 4 fl oz/A can be used on Clearfield Hybrids. Make two preflood sequential applications if no PPI treatment was applied. Flushing may be required for activation.
Postemergence (Midseason)			
Weedar 64 (2,4-D)	1 - 2.5 pt/A	Hemp sesbania, curly indigo, redstem, ducksalad, gooseweed, morning glory sp., and dayflower.	Apply between late tillering and ½ inch internode elongation. Add 1 pt of nonionic surfactant to each 50 gal or spray mix. Apply by helicopter or ground rig only.
Grandstand	0.67 - 1 pt/A	Hemp sesbania, northern jointvetch, morning glory, and redstem.	Apply up to midseason. Add a nonionic surfactant at 0.25-0.5% v/v. Do not apply to recently precision-graded fields.
Ultra Blazer	0.5 - 1.0 pt/A	Hemp sesbania	Add a nonionic surfactant at 0.25% v/v. Apply to rice before early boot stage.
Post-Flood (Salvage)			
Clincher SF	15 fl oz/A	Annual grass control	Apply within 2 weeks after flooding. Grasses should be above the flood with at least half of foliage exposed. Add a nonphytotoxic crop oil at 1 qt/A. Do not apply by air within 2 miles downwind or 4 miles upwind of peaches or nectarines.
Grasp	2.3 - 2.8 fl oz/A	Barnyardgrass and Ducksalad	Apply from flooding to 60 days before harvest. Add crop oil concentrate at 1% v/v.
Regiment	0.64 - 0.67 oz/A	Barnyardgrass	Apply before ½ inch internode elongation. Use an adjuvant approved by Valent.
Beyond	5 fl oz/A	Red Rice	Apply after two applications of Newpath for red rice escapes. Do not apply more than 14 days after panicle initiation.
Preharvest			
Sodium Chlorate	1.5 gal of a 3 lb/gal formulation	Desiccation of weeds and green rice.	Allow 7 days between application and harvest.

Red Rice Management

Red rice has been a weed problem in rice-growing areas for several years. As rice acreage has expanded recently in Mississippi, red rice has become an even more serious weed problem.

Botanically, red rice is the same species as cultivated rice, *Oryza sativa* (L.). It is actually a cultivar of rice. It reproduces itself and does not come from rice varieties genetically “running out.”Red rice is difficult to control in rice and is a strong competitor, reducing yields. Yield is reduced in proportion to the infestation. An extremely heavy infestation of red rice can reduce yields nearly 100 percent.

Red rice plants vary a lot in overall plant characteristics. The tall-growing, black-hulled, awned plant is easiest to recognize and is considered by many to be a typical red rice plant. However, other types have developed that have straw-colored hulls, are awnless, and are about the same height as desirable rice cultivars. This type of red rice is the most common kind in Mississippi. Red rice hides itself well.

Usually the red rice seed is shorter and wider than long-grain rice; therefore, some of the red rice seed can be removed by seed-processing equipment. But in the last few years, a long-grain red rice has appeared that cannot be removed by processing. This is the result of natural crossing that has occurred in the field.

Select Seed Source Carefully

Red rice infestations occur mostly because of seed or combine contamination. If combines are not thoroughly cleaned after harvesting a red rice-infested field, they can contaminate later-harvested, non-infested fields.

Make sure your seed does not contain red rice. Most pure seed laws permit some red rice in rice seed, but certified plantings are more restrictive. The Mississippi Seed Law allows up to nine red rice seed per pound of rice seed. No red rice seed can be present in any class of certified seed.

Seed bought directly from farmers does not have to meet state regulations, so this seed contains anything the farmer chooses to sell. Be sure to check your seed source and plant on fields that are free of red rice if possible.

Most red rice shatters before harvest. Almost all the seed produced remains in the field, resulting in heavy red rice stands and reduced yields the following year. Red rice seed can remain dormant in the soil for many years, making eradication difficult and requiring rotational crops to reduce infestations.

Cultural Control Practices

Management is the key to controlling red rice and reducing its competition with rice. These are some control measures that can reduce the red rice problem:

- Rotate rice with soybeans (preferably 2 years soybeans, 1 year rice).
- Control red rice plants in field borders.
- Remove any plants remaining in the field.

You must design the control program for 100 percent control. Control is almost impossible while a field is planted to rice unless it's planted to a Clearfield cultivar.

Red rice typically shatters before harvest, scattering seed across the ground. If you till the soil in the fall, those seeds are buried and can germinate in the years to come. Autumn rainfall encourages these red rice seeds to germinate. Flooding the fields in the winter provides habitat for waterfowl, which can feed on red rice seeds. Preparing land early before planting the rotation crop may produce another red rice seed germination flush that herbicides, preplant cultivation, and the planting operation can kill.

Most Mississippi rice soils are clay with lots of organic matter. Effective control in rotational crops with soil-applied herbicides requires from one to two times the normal herbicide rate. Also, a single soil-applied herbicide application seldom provides season-long control, since red rice germination occurs throughout the summer. Most soil herbicides provide effective control for 2 to 3 months. Make postemergence herbicide applications as needed to control escaped plants.

Chemical Control Programs Based on 3-Year Rotation

Year 1-Soybean

Preplant Incorporated: Treflan 2X, Dual, or Outlook.

Postdirected: Paraquat + nonionic surfactant two applications - when soybean are at least 8 inches tall. Make first applications before red rice is 3 inches tall and second application 7 to 10 days later.

Over-the-top applications:

- Assure II + nonionic surfactant or crop oil concentrate. Apply to red rice up to 4 inches tall. Repeat application on newly emerged plants when needed. Do not use vegetable (crop origin) oils as spray adjuvants or carrier with Assure II.
- Select + crop oil concentrate. Apply to red rice up to 3 inches tall. Repeat application to newly emerged plants when needed.
- Glyphosate (Glyphosate Resistant Soybean Only). Apply to red rice up to 3 inches tall. Repeat application to newly emerged plants when needed.

- Sequence (Glyphosate Resistant Soybean Only). This is a pre-mix of glyphosate plus Dual (metolachlor). Apply to emerged red rice up to 3 inches tall. This product can also provide residual control of red rice.

Seedhead Suppression of Red Rice in Soybean:
Select + crop oil concentrate or glyphosate applied from 4-inch joint movement until early booting when you detect first swelling in the flag leaf sheath. Repeat application when needed. See state label for specific and limiting application instructions.

Year 2-Soybean

Preplant Incorporated (PPI): Dual II or Outlook
Over-the-top applications: Same as year 1
Use these control measures in soybeans along with PPI and multiple postemergence applications:

- Mechanical cultivation – till shallowly several times in early spring or fall. Use a smoothing device with a tillage tool to stimulate red rice germination.
- Prevention - clean all machinery when moving from infested to noninfested fields.
- Hand rogue - remove the entire red rice plant. Parts of the rice plant not removed can still produce viable seed.

Year 3-Rice

Plant a Clearfield rice cultivar that is tolerant to Newpath and Beyond. Newpath may be used in two different application methods for red rice control:

- PPI or PRE application followed by a mid-postemergence application (3 to 4 leaf) or when red rice is 1 to 2 leaf.
- Early-postemergence application (1 to 2 leaf) followed by a preflood application.

Preplant incorporated application, a method where herbicide is incorporated into the soil using light tillage, typically controls red rice better than do preemergence applications, which are applied to the soil surface. For PPI/PRE applications, rainfall is needed within 3 days after planting or the field will need to be flushed. For maximum control with postemergence applications, red rice must not be drought stressed. If the soil is dry, flush the field before making a postemergence application of Newpath. Use Beyond to control any escapes from the Newpath applications. Always read the label before making any applications.

CHAPTER 9

Rice Diseases

John Damicone, Billy Moore, Joe Fox, Gabe Sciumbato, and Nathan Buehring

Rice diseases are influenced by cultivar susceptibility, seeding rate, environmental conditions, and intensity and frequency of rice culture within a given area. You can control certain diseases by using resistant cultivars, seed treatment, and better cultural and management practices. Diseases can cause substantial losses in yield and quality. All commercial cultivars have some resistance to certain diseases. When a troublesome disease persists, use a cultivar with higher resistance if available. Table 9.1 gives disease reactions of several cultivars.

You can reduce losses caused by rice diseases using these general control practices:

- Avoid unnecessarily stressing rice plants during the growing season with drought, fertilizer, chemical stress, and others.
- Apply recommended rates of nitrogen (N) and other crop nutrient fertilizers at the right time for the cultivar grown.
- Use foliar fungicides to help control specific diseases.
- Use a crop rotation that can keep disease organisms from building up.
- Plant the recommended seeding rate per acre.
- Plant on a well-prepared seedbed during recommended planting dates.
- Use high-quality seed, treated with an effective fungicide.
- Use cultivars with high resistance to the most common diseases in your area.
- Control weeds and grasses early.
- Destroy crop stubble as soon as possible.
- If possible, do not plant a blast-susceptible cultivar on fields with light soils.

Rice Diseases: A Guide to Identification

Rice is attacked by a number of diseases. Although some diseases are minor, others cause serious damage.

Rice diseases have become more common in the state for several reasons: increased rice acreage in Mississippi, repeated recropping of rice in certain areas and fields, and the limited availability of new land for long rotations. Soil-borne diseases, such as sheath blight, build up when fields are frequently cropped to rice. Also, rice grows in an aquatic system, resulting in a humid microclimate that favors disease development.

Short-growing, high-yielding cultivars, or semidwarfs, that respond to high nitrogen (N) rates have also contributed to disease increases. High N fertility increases susceptibility of rice to certain serious diseases, such as kernel smut.

Newer cultivars usually cost more money, making diseases that can cause partial or severe crop failure especially worrisome.

Proper identification of diseases is the first step in rice disease management. Some diseases can be managed by changing cultural practices or by planting a resistant cultivar. You may have a situation that requires a fungicide treatment, a costly control measure for a field crop like rice.

Correct Diagnosis Is Important

Knowing what disease is in the field is important. A correct disease diagnosis allows you to make economically wise management decisions and helps protect against crop failure. Before beginning treatment, make sure the disease is a damaging one and not a minor one. Do not ignore a serious disease because you think it is a minor one.

You can identify most rice diseases by their symptoms. This guide describes rice diseases that may occur in Mississippi.

Key characteristics that distinguish one disease from another are provided with pictures included. The following sections describe how serious each disease is, the ways each disease will probably affect the crop, and factors that contribute an infestation. Disease control methods, such as resistant cultivars and fungicides, are constantly updated. Keep track of the latest changes.

Disease symptoms can vary, so sometimes diagnosis based on symptoms alone is confusing. The following factors can affect disease symptoms: environmental conditions, varietal resistance or partial resistance, the stage of crop development, and normal aging of leaves and other plant parts. When these factors are at play, microscopic observations may be necessary to confirm a diagnosis. Contact your county agent to help you prepare samples to send to the Extension Plant Pathology

Table 9.1. Rice cultivar reactions to diseases[a].					
Cultivar	Sheath Blight	Blast	Kernel Smut	False Smut	Straighthead
Bowman	S	S	-	-	MS
CL 131	VS	S	S	MS	S
CL 161	VS	S	S	S	VS
CL 171-AR	VS	MS	S	S	MS
Cocodrie	S	S	S	S	VS
Cybonnet	VS	MR	S	S	MS
Sabine	S	S	VS	-	MR
Trenasse	VS	S	S	MS	MS
Wells	MS	S	MS	S	MS
XL 723	MS	R	MS	MS	MR

[a]Abbreviations: R=resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible, VS=very susceptible.

Diagnostic Laboratory, Mississippi State University. Some county offices have microscopes for such analysis.

Seedling Diseases

Seedling diseases contribute to poor seedling emergence, uneven stands, and stand failure. "Seedling disease" is a broad term that includes seed and seedling decay (preemergence damping off), and seedling blight (postemergence damping off). Several soil-borne fungi cause damping off, including *Rhizoctonia solani*, *Fusarium* spp., *Cochliobolus miyabeanus*, and *Sclerotium rolfsii*. Water molds, including *Pythium* spp. and *Achlya* spp., also cause stand losses. Water molds are often worse in water-seeded rice but can also affect drill-seeded rice.

Seedling diseases usually become a problem when untreated seeds are infected with disease organisms or when rice is growing poorly and under stress. Prolonged cool and wet conditions or unusually hot weather after planting may slow seed germination and seedling growth and favor seedling disease. Conditions that delay seedling emergence, such as poor seed quality, also increase seedling diseases.

Seed Rot and Damping Off

Failure of seedlings to emerge is the most obvious symptom of seed rot and preemergence damping off. A cottony growth in and around seed coats and the emerging seedlings is a symptom of water mold. Another symptom is a dark brown discoloration or rot at the growing point or root of germinated seedlings. The base of the leaf sheath and the roots of emerged seedlings have a similar dark brown or reddish-brown rot. Affected seedlings appear stunted and yellow and may soon wither and die. This event is called seedling blight.

Water molds are particularly severe in water-seeded rice culture. In states where fields are often water-seeded, dense and uniform stands are difficult to obtain. Seed rot caused by the water molds Pythium and Achlya, and sometimes the fungus Fusarium, are usually the cause of the problem. These fungi often occur together in a field. Through floodwater, water mold looks like balls of fungal strands spreading out from seeds on the soil surface. When the flood is removed using the critical-point method of water seeding, affected seeds are surrounded by a mass of fungal strands. The strands cause quarter-sized copper brown or dark green circles on the soil surface, with the rotten seed at the center. Bacteria and algae cause the colors of the spots. Unusually high or low water temperatures favor water molds. If seedlings are attacked after germination at pegging, they become yellow and stunted.

Seedling Blight

Wet, warm conditions favor seedling blight caused by *Sclerotium rolfsii* (southern blight). In soil infested by the fungus, large areas of plants may be killed, often along rows. Symptoms include a dark rot on the base of plants and a white moldy growth on lower plant parts. Round, small (less than 1⁄16 of an inch in diameter), tan to brown sclerotia attach to roots and lower leaves near the soil surface. Flooding affected fields immediately will stop southern blight progress.

Management

To manage seedling diseases, use both cultural and chemical methods:

- Correct low areas that collect water.
- Treat seed at the proper rate with a protective fungicide to minimize seed rotting and seedling blight in either drill- or water-seeded rice. See Chapter 4 and Table 4.5 for current control recommendations.
- Plant rice when temperatures can maintain active rice growth (soil temperature greater than 60 °F and average air temperature of 65 °F).

Foliage Diseases

Blast

Blast is one of the most damaging rice diseases in Mississippi. It is caused by the fungus *Pyricularia grisea* (formerly *Pyricularia oryzae*). Occurrence of blast is unpredictable because of yearly changes in weather, acreage planted to susceptible cultivars, and the development of new races of the fungus that attack cultivars resistant to other races.

Blast damages plants and reduces yield in several ways. Leaf spots or lesions reduce the effective leaf area. Lesions form on nodes of the stem and panicle, panicle branches, and the small panicle branches that support individual grains. These lesions cause girdling that results in incomplete grain fill or total grain failure. Losses in severely affected fields may exceed 50 percent.

Symptoms of blast differ depending on the part of the rice plant attacked. Phases of blast include leaf blast, nodal blast, collar rot, neck rot, and panicle blast.

Leaf blast occurs mostly in seedling and tillering stages of rice development. Plants under flood are generally resistant to leaf blast during internode elongation (jointing). Leaf spots are elliptical with pointed ends (elongated diamond shaped). The center of a spot is usually grayish or white with a brown or reddish-brown margin. The spots begin as water-soaked dots and rapidly expand to produce the typical leaf spot. Spots vary depending on varietal susceptibility, environmental conditions, and age. On more resistant cultivars, the spots are very small and rounded, with a thick brown margin. On highly susceptible cultivars, spots are large (0.4 to 0.6 inches long) and often have no dark margin but a yellow margin or halo surrounding the spot.

Plants grown under an adequate flood are generally more resistant to leaf blast than those grown where a flood is spotty or under dryland culture. Leaf blast in Mississippi is not considered a damaging phase of blast disease, but it does serve as a warning that blast will be a problem.

Nodal blast is possible but is not widespread in Mississippi. The stem (culm) nodes are affected and turn black, and the plant above the node soon dies. Infected mature nodes turn gray, shrivel, and often break over just above the node.

When the rice plants reach the reproductive stages, susceptibility to blast increases again. Collar rot occurs when the base of the flag leaf near the sheath is infected. The lesion extends upward on the leaf and downward on the sheath around the point of attachment. The lesion is grayish and sometimes has a brown border. If the lesion girdles the flag leaf, the leaf shrivels and dies, turns brown, and may eventually fall off.

Rotten neck is an infection of the uppermost node or panicle base, resulting in a girdling, dark lesion. With maturity, the panicle often breaks over at the lesion.

Panicle blast is an infection of the primary and secondary grain branches and the small branches that support grain (pedicels) in a fashion similar to rotten neck. Depending upon the stage of grain fill at infection, portions of the grain head (with panicle blast) or the entire grain head (with rotten neck) will be white instead of the green or tan color of healthy grain. This "blasted" appearance is caused by sterile, or blank, grain. Seed from infested fields is often contaminated with the blast fungus.

Certain practices and conditions favor blast development. Blast is associated with rainy, cool, overcast weather. Average daily temperature between 73 °F and 79 °F, prolonged leaf wetness, and relative humidity greater than 90 percent encourage disease development.

Excessive N fertilizer results in excessive growth and rice that retains moisture, both of which encourage disease development. Thick stands of rice also retain excessive moisture. Blast is also more common in rice grown on a light-textured soil.

An inadequate flood greatly increases the occurrence and severity of blast. Often a blast epidemic in a field begins in a high area or an area where the flood has been lost. Sandy soils and steep contours make flood maintenance difficult. The best way to control blast is to use resistant cultivars. Use both resistant cultivars and good cultural practices (proper field selection, seeding rate, fertilization, and flooding).

Management

- Plant a resistant cultivar. Refer to Table 9.1 for blast resistant cultivars.
- Plant early to avoid heavy blast pressure that can occur late in the season.
- Avoid using excessive N.
- Maintain a flood deeper than 4 inches. On fields that are difficult to maintain a 4-inch flood, consider using multiple-inlet irrigation. Refer to Chapter 7 for details.
- Scout intensively, especially on susceptible cultivars.
- If blast is present, consider using a fungicide. Refer to Table 9.2 for the latest fungicide recommendations.

Brown Spot

Brown spot, caused by the fungus *Cochliobolus miyabeanus* (formerly *Helminthosporium oryzae*), is a common disease in Mississippi. Brown spot may occur in rice from the seedling stage through maturity, but it is most severe at or near maturity. The disease occurs on leaves, leaf sheaths, panicle branches, glumes, and grain. Severe brown spot can be damaging and indicates plant stress.

Symptoms

Foliar symptoms are circular or oval brown spots that range from tiny dark spots up to ovals that are about ½ inch across. Smaller spots are reddish-brown to brown, while mature spots often have a gray center and a dark brown margin. Symptoms can occur anytime during the growing season, from the seedling stage until maturity. Spots on seedlings may become numerous, join together, and cause seedling blight. Spots on leaf sheaths are similar to those on leaves. Dark brown to black spots appear on glumes and may be large enough to cover the glume surface. Brown spots may also appear on the grain.

Damage from brown spot on seedlings occurs through reduced stands (seedling blight) or weakened plants. Leaf spotting of older plants is not considered a damaging phase of the disease, but severe brown spot on the panicle can reduce yield and grain quality.

Management

The occurrence of excessive brown spot usually indicates unfavorable growing conditions or poor soil fertility. These unfavorable conditions include inadequate N, cold-water areas near wells, root pruning by the rice water weevil, and areas of poor soil because of land forming operations.

To manage brown spot, maintain proper fertility levels and correct the factors causing the plant stress and poor growth. Treat seed with a fungicide to help control brown spot on seedling rice, which reduces both seedling blight and inoculum availability later in the season. Foliar fungicide applications are not recommended to control brown spot.

Brown spot has become less common and less destructive recently because of the increased rates of N fertilization used with modern cultivars.

Narrow Brown Leaf Spot

This disease has not been a problem in Mississippi but could become one; it does occur at damaging levels in nearby states. Narrow brown leaf spot is caused by the fungus *Cercospora oryzae*. In areas where the disease routinely occurs, it varies in severity from year to year. Heavy damage usually occurs on the most susceptible cultivars. Although the fungus attacks leaf sheaths, glumes, and occasionally nodes, it is most damaging as a leaf spot that reduces the effective leaf area. As with most foliar diseases, early infections are more likely to cause yield loss than late infections are. Severe leaf spotting may cause premature leaf death, ripening, and occasionally lodging.

The fungus produces airborne spores and probably survives in fields on infested rice debris. The pathogen may be seedborne.

Symptoms

Symptoms of narrow brown leaf spot on leaves and upper leaf sheaths include short, linear, brown spots. These lesions range in size from ⅛ to ½ inch long by 1⁄16 to ⅛ inch wide and run parallel to the leaf mid-rib. Lesions on resistant cultivars are short and dark brown. Lesions on susceptible cultivars are longer and have a gray center. Lesions become more numerous as the plant approaches maturity.

The fungus also causes a "net blotch" symptom on the lower leaf sheaths. Lesions are 1 to 2 inches long, reddish or purplish brown, with a netlike appearance. They may encircle the plant. Leaves of infected sheaths turn yellow and die.

Management

Some cultivars are less susceptible to narrow brown leaf spot than other cultivars are. Cultivars are bred for resistance to this disease. However, resistant cultivars generally become susceptible 3 to 5 years after release when new races of the fungus form and populations of the new race increase.

Several factors influence narrow brown leaf spot development: cultivar susceptibility, prevalence of a race capable of attacking a cultivar, and the stage of rice development. Plants are susceptible at all stages but are most susceptible from heading until maturity.

Fungicides can reduce losses caused by this disease, but unless the disease becomes severe in Mississippi, fungicides are not recommended. Contact your county Extension agent if you suspect narrow brown leaf spot.

Leaf Smut

Leaf smut is a widespread but minor disease of rice leaves caused by the fungus *Entyloma oryzae*. The disease usually occurs in Mississippi late in the season near maturity.

Symptoms

Symptoms of leaf smut are very small, black spots on both sides of leaves. They may be linear, rectangular, or elliptical. Many spots appear on leaves, but they remain separated. The spots (sori) are masses of black smut spores covered by the leaf epidermis. Spots may also develop on leaf sheaths and the culm (stem).

Severely infected leaves turn yellow and may split or die at the tips. The leaf smut fungus overwinters on old diseased leaves in the field, which provide inoculum for infections the next summer. The disease is spread by airborne spores. Because leaf smut occurs late in the season and causes little or no yield loss, no control measures are recommended.

Table 9.2. Fungicides for control of common diseases in rice.

Disease	Fungicide	Active Ingredient	Rate/Acre	Comments
Neck Blast	Gem Quadris	trifloxystrobin azoxystrobin	6.4 - 9.8 oz 12.5 - 15.5 fl oz	Apply to susceptible cultivars (Wells, Francis) that have leaf or collar blast or fields that have a history of blast. Apply at late boot to 10% heading. Follow with another application 5 to 7 days after first one (75% panicle emergence).
Sheath Blight	Quadris	azoxystrobin	9.0 - 12.5 fl oz	Higher rates may be needed for adequate control under high disease pressure. Do not use close to fishponds or orchards. High rates and two applications may be needed on highly susceptible cultivars such as CL 131, CL 151, or CL 161. Propi conazole containing fungicides cannot be applied after panicle emergence.
	Gem	trifloxystrobin	8 - 9.8 oz	
	Stratego	trifloxystrobin + propiconazole	16 - 19 fl oz	
	Quilt	azoxystrobin + propiconazole	28 - 34.5 fl oz	
	Moncut 70 DF	flutolanil	0.5 - 1.0 lb	Apply at ½" internode elongation to protect against sheath blight. Two applications may be necessary. Apply no more than 1.43 lb/A per growing season.
Kernel Smut and False Smut	Tilt	propiconazole	4 - 6 fl oz	These fungicides are applied to prevent kernel smut and suppress false smut. Apply at mid- to late-boot before panicle emergence. Propiconazole containing fungicides cannot be applied after panicle emergence.
	Propimax	propiconazole	4 - 6 fl oz	
	Stratego	trifloxystrobin + propiconazole	14 - 19 fl oz	
	Quilt	azoxystrobin + propiconazole	14 - 34.5 fl oz	

Leaf Scald

Leaf scald was first reported in the United States in Louisiana in 1971 and now occurs yearly in that state. It is caused by the fungus *Gerlachia oryzae* (*Rhynchosporium oryzae*) and has been observed in Mississippi, but the frequency and extent of occurrence are not known. The disease is of minor importance because the fungus usually attacks almost-mature leaves late in the season. The fungus is also reported to attack seedlings and panicles. The fungus is seedborne and survives on infested rice leaf debris. High levels of N fertilization favor leaf scald development.

Symptoms

The main symptoms of leaf scald are zonate lesions beginning at the leaf tip or edges of leaf blades. The lesions may have alternating light tan and dark reddish brown areas that make a chevron pattern on affected leaves. The leading edge of the affected leaf is usually yellow, making severely affected fields look golden. Affected leaves dry and appear straw colored. Affected panicles have dark, reddish-brown florets or grain hulls.

Because the disease generally occurs late in the season and is not considered serious, no controls are recommended.

Bacterial Panicle Blight

Bacterial blight has been found in Mississippi. The disease is caused by the bacterium *Burkholderia glumae*. In Asia the disease is severe, with yield losses approaching 60 percent. In the United States, the disease is caused by a mild strain of the bacterium.

Symptoms

In temperate regions of the world, symptoms of bacterial blight appear first in the flag leaf at heading. Lesions begin as water-soaked stripes at the margin of the leaf blade, near the tip. The lesions get bigger, turn yellow, and have a wavy margin. The border between healthy and diseased leaf tissue looks water-soaked as long as the disease is active. You may see milky or opaque water droplets on infected leaves when dew is present.

Blight lesions caused by severe strains of the bacterium elongate over the entire length of the flag leaf, making leaves look striped. Lesions caused by the mild strain are usually only 1 to 2 inches long and rarely as long as 7 inches. As lesions age, they become bleached white or tan and appear papery. They later become grayish as fungi grow on dead areas. Fields or areas in fields infested with bacterial blight appear white and ragged instead of green and healthy.

Panicles may be infected by the severe strain. Discolored spots with a water-soaked margin appear on glumes, in contrast to healthy, green panicles.

Little is known about the origin of bacterial blight in the United States or how it overwinters. The bacterium is short-lived in soil but is suspected to be seedborne. It is also short-lived on seed and may not survive well in seed lots over the winter. Weeds are thought to be the primary source of bacterial blight in parts of Asia where bacterial blight occurs frequently. The disease spreads by wind-blown rain, and disease development is encouraged by rain and high humidity.

The mild strain found in the United States seems to be spreading to new areas. Bacterial blight is a potentially dangerous disease that could flourish under Mississippi conditions. Contact your county Extension agent immediately if you suspect bacterial blight. The disease can be diagnosed quickly under a microscope.

Stem and Leaf Sheath Diseases

Sheath Blight

Sheath blight caused by the fungus *Rhizoctonia solani* has become the most important rice disease in Mississippi. The disease is widespread, occurs yearly, and reduces yields and milling quality. The disease has become more common and more severe since the 1970s. These increases were partly caused by the widespread planting of susceptible semidwarf cultivars and the high rates of N fertilizers used to produce high yields with these cultivars. Increased N rates appear to make plants more susceptible and make the environment within the rice canopy more favorable for disease development. R. solani causes numerous diseases of many crops. The strain that attacks rice also causes aerial blight of soybean.

Symptoms

Sheath blight affects leaf sheaths, leaves, and panicles. Early infections also attack the culm (stem). Culms weakened by sheath blight are prone to lodging. The main cause of yield loss is a reduction of effective leaf area. This effect is most severe when the disease attacks the flag leaf before grain fill. Incomplete grain fill reduces total yield and results in lower head rice yields because the poorly-filled grain breaks in milling.

Premature ripening associated with severe sheath blight also causes low moisture content in affected grain and makes it more likely to break during milling. Most yield loss is caused indirectly, not by direct blighting of panicles by the fungus.

The first symptoms of sheath blight usually appear sometime from late tillering through internode elongation. Spots appear on the leaf sheath near the water line. Spots are oval and range in size from ¼ to ⅜ of an inch wide and ⅜ to 1½ inches long. The size and color of spots vary with environmental conditions.

When the lower canopy is dry, spots have a white to tan, papery center and a brownish border. In high humidity, the spots have a gray to grayish white center and a dark gray border. Also in humidity, you can see white, web-like mycelium (mold) on the surface of spots and nearby green areas. The white mycelium, which you can usually see in morning dew, can help you distinguish sheath blight from other diseases that affect leaf sheaths.

As the disease progresses, mycelium moves onto the leaves of infected plants. From this surface growth, the infection invades healthy sheath and leaf tissue and causes new lesions. Growth speeds up during wet and humid conditions and slows down during dry periods. These periods of growth and infection cause an irregularly banded or "snakeskin" appearance to blighted areas. Each band represents a period of rapid growth. The centers of these new lesions are gray to papery white and have dark gray to brown borders.

The sheath blight fungus spreads to nearby plants when infected plants touch healthy plants or when the fungus grows on the floodwater surface. Under favorable conditions, the disease can blight all the foliage, including the flag leaf. Panicle infections occur during early heading when the emerging head touches nearby diseased foliage. The head is off-white and papery with dark brown blotches and does not branch or produce grain.

The fungus does not spread long distances, so infected plants are usually found in circular patterns of limited size. When tillers and plants in these circular areas die, they look gray from a distance and may join together with other affected areas to form large areas of dead, dying, or lodged plants. These areas are often most apparent near the edges of fields where wind-blown debris collects during early permanent flood. Several grassy weeds, including broadleaf signalgrass, can get sheath blight. They exhibit typical symptoms.

The level of primary infection (initial spots on lower leaf sheath) depends on how much sclerotia (survival unit) is in the field. Infested fields that have short rotation intervals with other crops or rice following rice develop a buildup of sclerotia.

The spread of the disease in the canopy and the amount of damage it causes depend on several factors. Compact, leafy cultivars favor disease development more than taller cultivars with a more open canopy do. Also, the disease must progress farther to reach the critical flag leaf on taller cultivars. Excessive fertilization and seeding rates create a dense, lush canopy that favors disease.

Weather also greatly influences sheath blight development. Infections occur when temperatures are 73 to 95 °F and humidity is greater than 90 percent. Temperatures from 86 to 90 °F create the best conditions for infection. Disease progresses most rapidly from heading to maturity.

Management

Control of sheath blight is difficult and requires an integrated management approach:

- Choose the least-susceptible cultivar based on current Extension recommendations for problem fields. No truly resistant cultivars of the long-grain type are commercially available. See Table 9.1 for resistance of commonly grown cultivars to sheath blight.
- Do not exceed recommended N or seeding rates for a given cultivar.
- Avoid alternate-year rice rotations. Do not plant consecutive rice crops. Surveys show these rotations result in higher levels of sclerotia and sheath blight compared to rotations where rice is cropped every third year.
- Scout fields thoroughly to determine the incidence of sheath blight if you are considering using fungicide. See Table 9.2 for current control recommendations.

Stem Rot

Stem rot disease, caused by the fungus Sclerotium oryzae, is one of the most common diseases in Mississippi and nearby rice-producing states. The disease is worse in fields with a long history of rice culture. Yield losses from stem rot are difficult to assess. It causes leaf sheaths and stem to rot, which can contribute to lodging. If the stem is rotted before grain fill, premature ripening and incomplete grain fill result. The disease often occurs in Mississippi, but any visible damage is usually limited to small areas of infested fields.

Symptoms

The first symptoms of stem rot appear near the waterline as small, dark brown to black, linear lesions ⅛ to ¼ of an inch long. Symptoms usually appear during internode movement stages of rice development. These lesions expand and become black angular blotches on lower leaf sheaths.

The disease progresses to cause a uniform dark brown and black discoloration (rot) of lower leaf sheaths near maturity. Leaves of affected sheaths die, turn tan to brown, roll around the mid-rib, and may keep their place in the rice canopy. Small, scattered patches of white mycelium (mold) may appear on the surface of rotted sheaths. When you peel back rotted leaf sheaths, you may see that the culm has the same angular black blotches.

In severe infections, internodal areas of the culm may have a general dark brown to black rot, making lower areas of affected tillers look water stained. The culm continues to rot as plants approach maturity. If culm rot is extensive, tillers break over between the nodes and lodge. Small black sclerotia develop in sheaths and stems from the time of maturity to after harvest. One telltale sign of stem rot is the presence of lots of sclerotia in sheaths and stems of affected mature plants or in the stubble after harvest.

Management

No commercial cultivars are highly resistant to stem rot, but early-maturing cultivars are less likely to get stem rot damage than are later-maturing cultivars. Excessive N fertility, K deficiency in soil, and overly dense seeding rates encourage stem rot development. Stagnant water remaining at the same flood level also favors disease development.

Deep incorporation of infested crop residue or burning of stubble after harvest reduces the level of inoculum available for infection. On the other hand, shallow incorporation of infested stubble after harvest can increase stem rot incidence and severity.

Because complete control of stem rot is impossible, use an integrated approach to management. Plant early-maturing cultivars instead of more susceptible late-maturing cultivars. Do not exceed recommended N levels or seeding rates for a given cultivar. Correct any K deficiencies according to soil test results. Stem rot damage is usually minimal with modern cultivars, so you probably will not see yield increases from water management and crop residue destruction programs.

Removing the flood increases the risk of blast. The advantages of increased pumping to change water levels are probably offset by current concerns about excessive water use for rice production in the Mississippi Delta. Achieving a complete burn of rice stubble in this area is difficult at best. Moldboard plowing for deep burial of inoculum is not economical. Some fungicides used for sheath blight control suppress stem rot development. However, it is unlikely that using fungicides to control just stem rot will be cost effective.

Black Sheath Rot

Black sheath rot is caused by a fungus, *Gaeumannomyces graminis* var. graminis, which is closely related to the fungus that causes "take-all" disease of wheat. The disease was first discovered in the United States in Arkansas in 1923 and has become more common in Mississippi in recent years. The disease appears to be a minor one in the state so far, but Texas and Arkansas have reported severe lodging, reduced number of panicles, reduced grains per panicle, and lower grain weight per panicle. The disease could reduce yield through premature ripening, incomplete grain fill, reduced tillering, and lodging.

Symptoms

Symptoms of black sheath rot in Mississippi have first appeared as spots on lower leaf sheaths in the mid to late joint elongation stages. The color of spots can vary, even on tillers of the same plant. Spots are ¾ to 1½ inches long and about ⅜ of an inch wide. They are gray or brown. The spots get bigger but stay only on the leaf sheath. Discoloration may remain gray with a black or brown upper and lower border. When you peel back the rotted leaf sheath, you can see dark reddish-brown strands of the fungus (mycelium) on the inner surface of the leaf sheath.

When sheath rot becomes extensive, the attached leaf is killed, turns tan or light brown, and retains its position in the canopy. The black, pepper-like, fruiting structures of the fungus somewhere in the discolored areas is an excellent way to distinguish this disease from other sheath diseases.

When black sheath rot is severe during heading, all the leaf sheaths except those of the flag leaves become infected and rot. The attached leaves die. The lower plant appears dark brown or black at this stage. When you pull back the sheaths, you may see black rings or "eyespots" on the internodes. The nodes rot and turn dark brown or blac

Black fruiting structures of the fungus are numerous during heading in the sheath tissue. If lodging occurs, the stems break over at the nodes rather than between the nodes, as with the stem rot disease. The dark fruiting structures look like the sclerotia of the stem rot disease, but they appear earlier with black sheath rot than with stem rot.

The disease appears different from sheath blight because no white mycelium appears on or near affected areas and leaves are not directly attacked.

Management

Factors that favor black sheath rot development are not well defined. The disease in Mississippi occurs more frequently and severely on sandy soils than on heavy clay soils.

Because the disease appears to be of minor economic importance, no controls are recommended. Proper identification of this disease is critical, as it can resemble other diseases. Mistaking black sheath rot for sheath blight can be costly if you initiate a fungicide program.

Sheath Spot

Sheath spot is caused by the fungus *Rhizoctonia oryzae*, which attacks leaf sheaths. Symptoms closely resemble early sheath blight infections. The disease does not develop extensively in the rice canopy and is not economically important.

Symptoms

Spots, or lesions, usually appear on leaf sheaths midway up the tiller. Spots are oval, $\frac{3}{8}$ to $\frac{3}{4}$ of an inch long, and $\frac{3}{16}$ to $\frac{3}{8}$ of an inch wide. Spots usually occur on the upper leaf sheath near the leaf blade. The spots have white to pale green centers with a broad, dark, reddish-brown border. These spots remain separated and do not progress extensively on the leaf blade. Usually the leaf base is the only part of the leaf blade that is attacked, along with a spot on the sheath.

Unlike sheath blight, sheath spot does not have fungal growth (mycelium) extending from spots over adjacent green areas. Also, sheath spot does not have sclerotia near older infections or continuous, extensive lesion development on leaves and tillers from initial infection. In Mississippi the disease often appears later in the season than sheath blight does.

Fungicides targeted for sheath blight give little or no control for sheath spot. No controls are recommended for sheath spot.

Sheath Rot

Sheath rot disease, caused by the fungus *Sarocladium oryzae*, usually occurs on the flag leaf sheath (boot) that encloses the panicle. The disease is generally of minor importance and scattered within fields, but occasionally areas within fields develop sheath rot at a level that affects yield.

Symptoms

The lesions first appear as oblong or irregular spots about $\frac{3}{16}$ to $\frac{5}{8}$ of an inch long. They may have a gray center with a reddish-brown margin, or they may be completely reddish brown. Lesions are usually completely reddish brown on United States long-grain cultivars.

Lesions may also form an irregular target appearance. Lesions will enlarge and join to cover most of the sheath. If the sheath is infected before head emergence, the panicles may not emerge. If infection occurs during emergence, the panicle partially emerges. Abundant white powdery growth of the fungus is later visible inside affected leaf sheaths and on the surface of rotted panicles. Panicles of sheaths affected before emergence will rot, turn brown or reddish brown, and fail to produce any grain.

Insect or mite damage to the boot increases the occurrence and damage of this disease. Most rice cultivars are susceptible to sheath rot.

No control measures are recommended because of the minor importance of the disease.

Dead Tiller Syndrome

"Dead Tiller Syndrome" was first observed recently in northeast Arkansas and has since been found in Mississippi. The cause is the fungus *Pythium arrhenomanes*. Symptoms develop 6 to 10 days after establishment of permanent flood.

Symptoms continue to develop for about 8 to14 days until the temperature of the floodwater stabilizes. If cold water is continually pumped into the field, symptoms may continue throughout tillering. Initial symptoms are the appearance of discolored tillers and some wilting. Advanced symptoms include severe wilting of tillers and yellow or orange leaf tips or margins on some plants.

Tiller death occurs soon after the onset of symptoms. Dead tillers at first stay green but then turn brown. Dead tillers become dislodged from plants and float on the water. If you split an affected tiller, you can see an internal rot that begins at a node. Symptomatic tillers are usually very decayed and have a foul odor. The main, or oldest, tiller is usually affected and rolls up. The disease does not appear to spread from infected tillers to healthy tillers or plants.

The disease has not been very important in Mississippi because only a small percentage of plants are affected and nearby plants seem to compensate for any loss in tiller density. In Arkansas, yield reductions have been observed in cold-water areas as the disease progresses over a longer period of time. Most commercial rice cultivars appear to be susceptible to dead tiller syndrome. No control measures are available.

Panicle and Grain Diseases

Kernel Smut

Kernel smut, caused by the fungus *Neovossia barclayana*, is becoming more important in Mississippi. Planting susceptible cultivars and using high rates of N fertilizer have led to occasional economic losses. The disease may cause a slight loss in total yield. Rice mills may dock or refuse shipments that contain a high incidence of kernel smut.

Symptoms

Symptoms of kernel smut are first noticeable as the crop approaches maturity. Symptoms include black streaks or spots on grain. The black spores of the fungus replace a part or all of the infected rice grain. Under high moisture conditions, the spores swell and balloon out from the hull, looking like a black mass. The mass becomes powdery and is easily removed from infected grains by rubbing. Usually only one to five grains are affected per panicle, but much higher levels of infection are possible. Infected rice that is milled looks dull or gray. Kernel smut is most important in rice that is sold for parboiling because partially filled, discolored grains often break in milling.

Disease Cycle

Unlike smut diseases of other grain crops, kernel smut does not cause systemic infection of plants from seed transmission. The spores can overwinter in smutted kernels on the soil or be carried to fields on infested seed. The spores germinate the following year and produce many secondary spores as infected kernels float on floodwater or live on the wet surface of levees. Spores are forced into the air and contact florets on developing panicles. If conditions are favorable during flowering (light showers, high humidity, temperatures from 77 to 86 °F), spores germinate and infect the florets. Infected florets then develop into smutted kernels.

The disease is favored by rank growth of rice under high N conditions. It is most severe on sandy loam soils and in high-fertility areas of fields.

Management

Neither seed treatments nor foliar-applied fungicides have been effective in reducing the incidence of kernel smut. The following cultural practices will help prevent this disease:

- Rotate crops.
- Choose a resistant cultivar. Refer to Table 9.1 for information on the reaction of rice cultivars to diseases.
- Manage N properly. Avoid high N rates and late N applications.
- Make a preventative fungicide application. Refer to Table 9.2 for currently labeled fungicides.

Straighthead

Straighthead is a physiological disorder that causes sterile panicles. There is no known pathogen associated with the disorder. Straighthead occurs most frequently in rice planted in sandy soils with a high organic matter content or in soils with arsenic residues, usually from application of MSMA to previous crops or from old cotton insecticides. Straighthead is of minor importance in Mississippi because most rice is planted on clay soils. Where it occurs, affected plants are usually localized within fields.

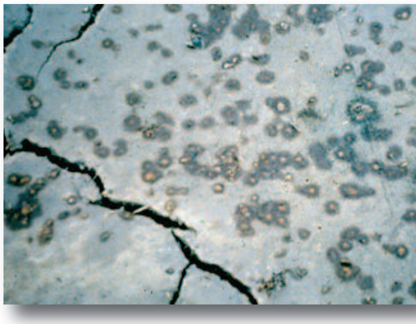
Symptoms

Affected panicles remain upright instead of bending over as the grain fills. Panicles are completely or partially sterile. Typically, the hulls appear crescent or half-moon shaped. Severely affected plants may completely fail to head. Before heading, affected plants are often darker green than surrounding plants. Affected plants may also remain green at maturity.

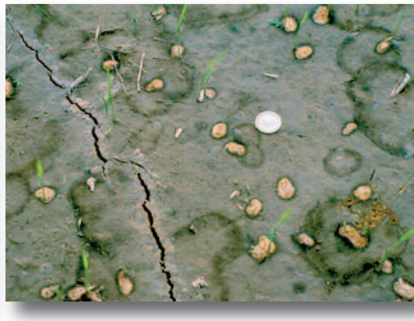
Management

- Plant resistant cultivars in fields with a history of straighthead problems. Refer to Table 9.1 for information on the reaction of rice cultivars to diseases. If you plant a susceptible cultivar, drain problem fields and dry 2 weeks after permanent flood is established to control straighthead.

Disease Indentification Guide



1. Pythium Water Mold



2. Achylia Water Mold

3. Seedling Blight

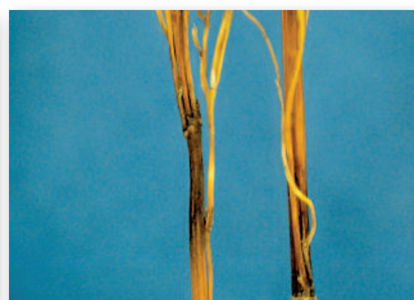
4. Seedling Cold Injury

5. Severe Blast

6. Leaf Blast

7. Leaf Blast

8. Panicle Blast



9. Rotten Neck and Panicle Blast

10. Brown Spot

11. Narrow Brown Leaf Spot

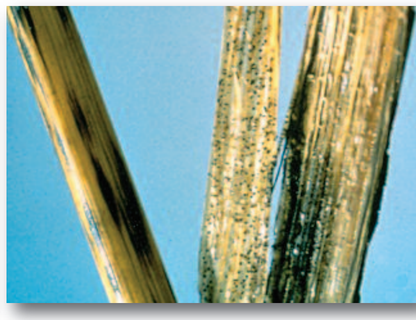
12. Leaf Smut


13. Leaf Scald


14. Bacterial Leaf Blight


15. Stem Rot


16. Stem Rot

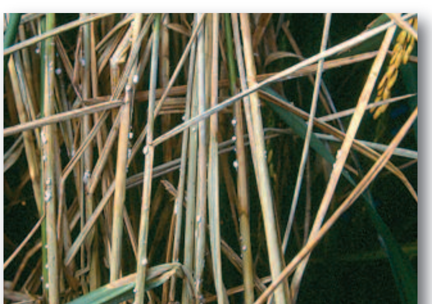

17. Stem Rot Sclerotia in Leaf Sheath


18. Sheath Blight


19. Sheath Blight Lesions

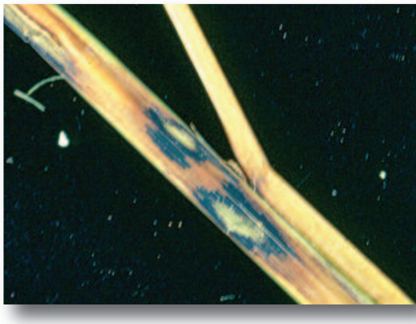

20. Sheath Blight in Top of Rice Canopy


21. Sheath Blight in Panicle


22. Young Sclerotia
of Sheath Blight Fungus


23. Mature Sclerotia
of Sheath Blight Fungus


24. Lodging Caused
by Sheath Blight



25. Black Sheath Rot

26. Black Sheath Rot

27. Severe Black Sheath Rot

28. Lodging caused by Black Sheath Rot

29. Sheath Rot

30. Dead Tiller Syndrome

31. Kernel Smut

32. Straight Head

33. Pecky Rice

Contributors

Photographs 1, 2, 3, 4, 13, 14, and 33 were provided by Dr. Clayton Hollier, Extension Plant Pathologist, Louisiana State University.

Photographs 7, 17, and 28 were provided by Dr. Glen Whitney, Research Plant Pathologist, Texas A & M University.

CHAPTER 10
Rice Insects

Jim Robbins and Nathan Buehring

Several insects are found in rice fields, and some cause economic damage. In Mississippi, rice water weevil and rice stinkbug are the main insect pests. Chinch bug, fall armyworm, and grasshopper may cause damage but are usually localized. Use control measures only when the infestation level is high enough to cause financial losses. The primary insects and control measures are discussed below.

Rice Water Weevil

Rice water weevils occur throughout Mississippi's rice-growing area. Fields planted to rice for several years usually have larger populations than fields recently brought into production. The adults are grayish brown, broad nosed, and about ⅛ inch long.

Adults overwinter in grasses and ground trash near rice fields. They are strong fliers and migrate into rice fields in the spring. Adult weevils may be found in rice before flooding but usually invade fields in large numbers soon after flooding. If the field is flushed, water weevils may be attracted into the field before a permanent flood is established. Weevil activity is more common in areas with open water, such as around levees and thin stands. Higher populations are usually found in fields flooded between late May and mid-June.

Adult weevils feed on the leaves of rice plants. They remove portions of the upper leaf surface, resulting in a feeding scar. These feeding scars are about the width of a pencil line and ½ inch to 2 inches long. They are usually parallel with the midvein of the leaf. The scars are usually white but may be tan or brown. Wind may cause the thin layer of tissue in the scar to break loose and leave a hole in the leaf. The adult leaf feeding does not seriously damage rice plants but does indicate whether or not adult weevils are present. The adults move into a field of rice and lay eggs on young plants. After the eggs hatch, the larvae move down the plants to the root system. The larvae, or root maggots, feed on the root system. They can injure plants seriously by pruning the root system. Larvae are white, legless, and up to ¼ inch long. They feed on the root system for about 3 weeks, until they pupate. Weevils spend about 2 weeks in the pupae stage before emerging as adults.

To determine if an insecticide treatment is needed, inspect the field. Start checking fields within the first few days after flooding. Rice fields with a history of water weevil infestations are more likely to require treatment than those without a history of damaging water weevil populations. Adults usually appear first in areas where water is deep and stands are sparse, exposing open water. Populations are heavier around open areas and levee ditches than in thicker stands in bay areas. Check these areas for signs of adult feeding, but do not decide to treat based only on weevil counts from such areas. They may not be representative of the infestation level in the other, more typical plant population areas of the field. Check six or more locations that are representative of rice plant populations. Correct timing of the insecticide application is necessary for acceptable control. Apply an insecticide when adults and feeding scars are observed and conditions are good for egg laying. Treat the fields within the first 7 days after establishment of the permanent flood. Data from other rice producing states shows that a pyretheroid application up to 5 days before flooding can provide effective control of rice water weevil adults. Generally, one application of insecticide has provided effective control. A second application may be needed in areas with severe water weevil populations. Refer to Table 10.1 for insecticide control recommendations.

Rice Stinkbug

The adult rice stinkbug is light brown and shield shaped. It spends the winter in clumps of grass and other ground litter before emerging in the spring to feed on grasses. The adult migrates to rice soon after rice begins to head. There it feeds and deposits eggs. Both the adults and the developing young feed by sucking juice from the developing kernels. Feeding on the milk stage of rice produces blank grains. Feeding on the soft dough stage can cause peckiness of grains, but peckiness can also be caused by other factors. Start checking the rice fields when rice is about 10 percent headed. Sample four to six locations. Sample with a sweep net, making 10 sweeps in 180° arcs in front and to your sides. Hold the sweep net so that the open mouth of the net makes contact with the heads of the rice plants, capturing any insects on the rice head. Scout fields at least once a week until rice heads are mature.

When you find an average of 5 stinkbugs in 10 sweeps during the first 2 weeks of heading, treat the area or the field. After the field is completely headed and most of the heads are in the milk stage, treat when you find an average of 10 stink bugs in 10 sweeps.

Mowing grass around the edges of rice fields can decrease rice stinkbug populations in the field. Grasses may host the rice stinkbug, so mowing eliminates potential stinkbug habitat.

Fall Armyworm

Occasional outbreaks of fall armyworms occur in rice fields. These insects feed mostly on leaves and stems of unflooded rice. They may move out of nearby wheat fields and grassy areas into fields that have seedling rice plants. Submerging the crop with water usually provides an effective control. If the rice plants are too young to be flooded, use an insecticide. These insects occasionally occur in headed rice and if left uncontrolled will cause substantial yield losses. Treat when you find an average of 5 or more worms per 10 sweeps or when you see considerable damage.

Grasshopper

Several species of grasshoppers may be found in rice fields. Green grasshoppers from the longhorn species usually feed on the flower parts of the plants. The brown species feed on leaves and the sides of stems of rice plants. Injured plants will sometimes produce white heads.

Grasshoppers are very seldom an economic problem in rice fields. However, during drought conditions, large numbers may move into fields as food plants around the fields dry up. In most situations, only border treatment is necessary to control a damaging population. Use the same sweep net sampling technique described in the section on stink bug sampling to determine if an insecticide treatment is needed.

Chinch Bug

Chinch bugs will occasionally attack seedling rice. Check rice frequently the first 3 weeks after emergence. The first instar nymphs are orange and about 1⁄16 inch long. As chinch bugs mature through instars, they become black with conspicuous wing pods. They feed mostly on the rice stems just below the surface of the soil, which causes the plants to wither and die. Flooding or flushing will help control this pest, but an insecticide application may still be necessary.

Insecticides may also be used to control chinch bugs. Because these insects are most active late in the day and at night, apply insecticides very early in the morning or late in the day for best results.

Cattail Billbug

A condition known as whitehead sometimes occurs in rice because of feeding by cattail billbugs. In Mississippi, this problem has not been severe enough to cause serious economic loss, but it is severe on rice levees. Dry soil around field perimeters will also cause whitehead.

Table. 10.1. Rice insect control recommendations.

Insect	Insecticide	Product/Acre	lb ai/A	Acres/Gallon	Comments	Preharvest Interval
Chinch Bug	lambda-cyhalothrin		0.025 - 0.04		Treat when stand loss occurs. Methyl parathion may be applied 7 days before or after a propanil application. Do not tank-mix carbaryl with propanil or apply within 14 days of a propanil application. Flushing or flooding alone may not control chinch bugs.	21
	Karate Z 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Lambda 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Zeta-cypemethrin		0.165 - 0.025			14
	Mustang Max 0.8 EC	2.64 - 4.0 fl oz/A		32 - 48.5		
	gamma-cyhalothrin		0.0125 - 0.02			21
	Prolex 1.25 CS	1.28 - 2.05 fl oz/A		62 - 100		
	Proaxis 0.5 CS	3.2 - 5.12 fl oz/A		25 - 40		
	carbaryl		1 - 1.5			14
	Sevin 80 S	1.25 - 1.87 lb/A				
	Sevin XLR or 4L	2 - 3 pt/A		2.7 - 4		
	methyl parathion		0.50			15
	Methyl 4 EC	1 pt/A		8		
	Penncap-M 2 EC	2 pt/A		4		
Fall Armyworm	lambda-cyhalothrin		0.025 - 0.04		Treat when you find 5 worms per 10 sweeps or when significant amount of foliage is being affected. Methyl parathion may be applied 7 days before or after a propanil application.	21
	Karate Z 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Lambda 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Zeta-cypemethrin		0.02 - 0.025			14
		Mustang Max 0.8 EC	3.2 - 4.0 fl oz/A		32 - 40	
	gamma-cyhalothrin		0.0125 - 0.02			21
	Prolex 1.25 CS	1.28 - 2.05 fl oz/A		62 - 100		
	Proaxis 0.5 CS	3.2 - 5 .12 fl oz/A		25 - 40		
	carbaryl		1 - 1.5			14
	Sevin 80 S	1.25 - 1.87 lb/A		2.7 - 4		
	Sevin XLR or 4L	2 - 3 pt/A				
	methyl parathion		0.50			15
	Methyl 4 EC	1 pt/A		8		
	Penncap-M 2 EC	2 pt/A		4		
Grasshopper	lambda-cyhalothrin		0.025 - 0.04		Treat when damage by grasshoppers is evident. Methyl parathion may be applied 7 days before or after a propanil application. Do not tank mix carbaryl with propanil or apply within 14 days of a propanil application.	21
	Karate Z 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Lambda 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Zeta-cypemethrin		0.02 - 0.025			14
	Mustang Max 0.8 EC	3.2 - 4.0 fl oz/A		32 - 40		
	gamma-cyhalothrin		0.0125 - 0.02			21
	Prolex 1.25 CS	1.28 - 2.05 fl oz/A		62 - 100		
	Proaxis 0.5 CS	3.2 - 5.12 fl oz/A		25 - 40		
	methyl parathion		0.5			15
	Methyl 4 EC	1 pt/A		8		
	Penncap-M 2 EC	2 pt/A		4		
Rice Water Weevil (eggs)	diflubenzuron		0.19 - 0.25		Apply an insecticide when adults and feeding scars are observed and conditions are favorable for egg laying. This insecticide kills the eggs of rice water weevil. Apply 2 to 5 days after the permanent flood has been established.	80
	Dimilin 2L	12 - 16 fl oz/A		8 - 10.6		

Insect	Insecticide	Product/Acre	lb ai/A	Acres/Gallon	Comments	Preharvest Interval
Rice Water Weevil (adults)	lambda-cyhalothrin		0.025 - 0.04		Apply an insecticide when adults and feeding scars are observed and conditions are favorable for egg laying. This insecticide kills only adult rice water weevil. Apply within a week of permanent flood establishment.	21
	Karate Z 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Lambda 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Zeta-cypemethrin		0.02 - 0.025			14
	Mustang Max 0.8 EC	3.2 - 4.0 fl oz/A		32 - 40		
	gamma-cyhalothrin		0.0125 - 0.02			21
	Prolex 1.25 CS	1.28 - 2.05 fl oz/A		62 - 100		
	Proaxis 0.5 CS	3.2 - 5.12 fl oz/A		25 - 40		
Rice Stink Bug	lambda-cyhalothrin		0.025 - 0.04		First 2 weeks of heading: 5 stinkbugs/ 10 sweeps	21
	Karate Z 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Lambda 2.08 CS	1.6 - 2.56 fl oz/A		50 - 80		
	Zeta-cypemethrin		0.0165 - 0.025		From dough stage until 2 weeks before harvest: 10 stinkbugs/10 sweeps	14
	Mustang Max 0.8 EC	2.64 - 4.0 fl oz/A		32 - 48.5		
	gamma-cyhalothrin		0.0125 - 0.02			21
	Prolex 1.25 CS	1.28 - 2.05 fl oz/A		62 - 100		
	Proaxis 0.5 CS	3.2 - 5.12 fl oz/A		25 - 40		
	carbaryl		1 - 1.5			14
	Sevin 80 S	1.25 - 1.87 lb/A				
	Sevin XLR or 4L	2 - 3 pt/A		2.7 - 4		
	methyl parathion		0.5			15
	Methyl 4 EC	1 pt/A		8		
	Penncap-M 2 EC	2 pt/A		4		
	malathion		0.625 - 0.94			7
	Malathion 57% EC	1 - 1.5 pt/A		8 - 16		
	Malathion 5	1 - 1.5 pt/A		8 - 16		
Stem Borers	lambda-cyhalothrin		0.031 - 0.04			21
European Corn Borer	Karate Z 2.08 CS	1.92 - 2.56 fl oz/A		50 - 67		
Mexican Stalk Borer	Lambda 2.08 CS	1.92 - 2.56 fl oz/A		50 - 67		
Rice Stalk Borer						
Sugarcane Borer						

Draining Rice, Maintaining Yield and Grain Quality

Theodore Miller and Joe Street

Timely drainage before harvest is important to rice maturity and harvesting efficiency. The right time to drain depends on crop maturity, soil type, drainage facilities, weather conditions, and time of season. Remember that weather conditions affect how long it takes soils to dry.

To prepare for draining and harvest, stop all irrigation 3 to 5 days before the scheduled drainage date. Drain fields to ensure that enough moisture is available to the rice plants so the later florets (grain) on the rice panicle (head) can be properly filled before the harvest. The field must be dry enough that the soil surface will support harvesting equipment without severely rutting the field. Drain by cutting field levees and perimeter levees.

Fields of heavy soils, such as clays, are ready for drainage when the top half of the panicles are yellow and turned downward. Fields of lighter soils, such as silt loams and sandy soils, are ready to be drained when the top two-thirds or three-fourths of panicles are yellow and turned downward.

Harvesting

Rice is generally harvested when the moisture content is between 18 and 21 percent. At this growth stage, the kernels on the lower portion of the head are in the hard dough stage. If rice is harvested when the moisture level is too high, more light, chalky kernels will be present, reducing the amount of head rice and total milled rice. Harvesting rice at low moisture levels causes shattering and broken kernels.

To sample for moisture content, use a combine to harvest a representative sample from a small area in the field. Hand-harvested samples do not accurately indicate rice moisture content.

Begin harvesting when the grain moisture content is about 21 percent. This moisture level usually promotes efficient harvesting of upright plants, reduces shattering and mechanical breakage, and makes it possible to complete the harvest before the grain moisture content gets too low, which may reduce milling quality.

A standard combine will harvest rice, but a rice combine, which is equipped with special options, can produce a more efficient harvest. In most cases rice combines have a pick-up reel to help with lodged rice and spiked-tooth cylinders to help with grain threshing.

The Shellbourne Reynolds stripper header is a new type of rice harvesting equipment. A stripper header harvests very efficiently, reduces the amount of plant material that passes through the combine, and produces a cleaner rice sample.

Special cutter bars can help harvest lodged rice and can be installed on combine headers if needed. When harvesting lodged rice with a pick-up reel, operate the combine in the same general direction as the rice has lodged.

Combine adjustments that allow satisfactory removal of foreign matter without blowing rice from the combine are important. Because there are many different types of threshing mechanisms in today’s combines, it is very important to consult the operator's manual for proper adjustments. You can also consult a dealer representative to help you adjust a combine properly. You may have to adjust combines a few times a day while harvesting in response to crop moisture and environmental conditions.

Classification of Harvest Losses

Preharvest losses are grain losses caused by birds, weather, and other factors before harvesting begins.

Management losses are grain losses caused by poor management, including decisions about draining fields, timing harvests, operating combines, and others.

Combine losses are grain losses caused by the improper adjustment and operation of the combine. These fall into two categories:

- Header losses, which are caused by shattering, lodged stalks (down rice), and loose stalks.
- Threshing and separating losses, which are caused by improper adjustments of combine threshing and separating components.

Calculating Harvest Losses

You can determine rice-harvesting losses by counting the number of seed per square foot you find on the ground behind the header or discharge of the combine during harvesting. When you measure rice grain losses behind the combine, disconnect or disengage the straw spreader or chopper. Depending on variety, about 20 seed per square foot equals 1 bushel lost per acre.

When you make counts directly behind the combine header, you can convert the loss per square directly to bushels per acre based on 20 seed/ft^2.

When you make counts behind the discharge of a combine, additional calculations are necessary to determine grain loss in bushels per acre. To determine the actual bushels per acre loss, you will have to consider the size of the header and discharge on a combine. Let's suppose the combine has a 20-foot header and a discharge housing width of 4 feet. Let's further suppose the seed counted in a 1 square foot area behind the discharge was 170 seeds.

So: Header = 20 ft
Discharge = 4 ft
Seed loss/ft^2 = 170

1. Divide discharge size into header size to determine the ratio of harvested area to the combine discharge area.

   $^{20}\!/_4$ = 5, so 5 ft^2 of header area is equivalent to 1 ft^2 of discharge area.

2. Divide the actual number of seed counted behind the discharge by the answer to step 1.

   In this example, the answer to step 1 was 5.
   $^{170}\!/_5$ = 34, so 34 seeds are lost per square foot of harvest area.

3. Subtract the seed loss behind the combine header from the answer to step 2.

   Let's suppose the seed loss behind the combine header was 3 seeds per square foot. Subtract 3 seeds per square foot from the 34 to determine threshing and separating losses. 34 - 3 = 31, so 31 seed/ft^2 are lost due to threshing and separating.

4. Now, divide the corrected seed loss (your answer from step 3) by 20 to convert seed loss to bushels per acre.

   $^{31}\!/_{20}$ = 1.55 bushels per acre due to threshing loss

When the combine cylinder is operated at speeds higher than required, over-threshing damages the rice kernels and breaks them in the milling process, causing lower milling yields. As a general rule, never operate the cylinder faster than is necessary to remove the rice kernels from the head. Excessive cylinder speeds can break the straw into such fine fragments that separation is extremely difficult. It would be better to use spike bars in the concave than to increase cylinder speed.

Drying and Storage

Temperature and moisture content of freshly harvested rice affect how long it will keep. Some cooling must begin within 12 to 24 hours of harvesting. Cooling within 12 hours is best. The amount of time between harvesting and cooling rice is especially important when its moisture content is high and the outside temperature is warm.

Excess grain moisture is the main problem in storing rice. You can safely harvest rice by combine when its moisture content is between 18 and 21 percent, but you cannot safely store it at that moisture level. If you delay harvesting to allow all grain to dry completely in the field, weather conditions may cause considerable loss. Here are the advantages of on-farm drying and storage:

- Harvest early to reduce grain breakage and the chance of weather-related losses.
- Time the harvest to maximize grain quality and quantity.
- Harvest at your convenience and speed.
- Reduce spoilage by storing grain in appropriate facilities.
- Store rice to permit versatile market management.

Drying is the most widely used method of conditioning wet grain to preserve its quality, food value, and ability to germinate.

Carefully plan drying facilities before construction. Errors in design or location are difficult to correct after construction has begun. Poorly planned, inefficient facilities are inconvenient and can increase labor requirements.

Lay out bins to fit your needs. Plan an arrangement that can provide efficient grain handling, has plenty of working space, and allows future expansion. Locate bins on a well-drained area that will not flood. Bins should be close to an electrical power source and fit in with existing facilities.

A corrugated metal bin with full, perforated-metal floors, tightly built to protect rice from weather, insects, and rodents, is essential for rice drying on the farm. Basic equipment includes drying fans and heaters, humidistat and thermostat controls, and grain handling gear. Optional equipment includes grain stirring devices, plenum temperature thermometers, grain spreaders, and grain temperature monitors.

Dry rice by moving large volumes of unheated or heated air over the grain so the moisture content of the grain is higher than the moisture content of the air. The moisture moves from within the grain to the surrounding air.

To keep stress from cracking the grain, remove moisture from the rice slowly. Cracked kernels have lower milling quality. In on-farm drying facilities, apply only the minimum amount of heat so that the movement of moisture will be gradual from the inner core of the kernel to the outer layer. Added heat should not be more than 10 degrees above outside temperature or above 100 °F.

Drying rice on the farm is much easier if the drying bin has stirring devices. Stirring devices used in batch drying operations reduce the static pressure the fan must work against. If the fan can move enough cubic feet per minute (cfm) of air per bushel, you will be able to dry more than a 6-foot depth of rice.

Clean the bins thoroughly before loading them with rice. They should also be dried, weather- and rodent-proofed, and treated for insects. This is essential to have high quality grain that will bring the best possible price.

You can do on-farm drying in one or more of the following ways: batch drying with heated air, layer drying with heated air, and bin drying with unheated air.

Batch Drying with Heated Air

When batch drying with heated air, put the rice 6 feet deep in a bin with a perforated floor. The fan capacity determines how deep the rice can be. Force air through the grain at a rate of at least 3 cfm per bushel.

If the moisture content is greater than 20 percent, use a rate of at least 4 cfm per bushel. The higher rate of airflow helps avoid excessive heating in the upper rice layers. Make sure that high-moisture rice is always level on top. Transfer it to another bin after 2 to 3 days of drying. Transferring rice every 3 to 4 days thereafter will improve grain quality, as the blending promotes more uniform grain moisture.

With this method, increase the air temperature 10 °F above the outside temperature; never allow the inside temperature to exceed 100 °F. Do not reduce airflow just because heat is being added. Supplemental heat will not make up for inadequate airflow. By limiting the temperature rise to 10 °F, you decrease the possibility of stress cracking (checking) the rice kernels. Batch drying with heated air is usually used to dry rice with a moisture content between 16 and 24 percent. When the moisture content of the grain has been reduced to 16 percent, you can move the grain to another bin where the airflow is reduced, the grain is deeper, and more attention is given to the relative humidity of air being passed through the grain. You reduce the possibility of stress cracking and overdrying the rice during this latter stage, since you are using a slower rate of drying.

Stirring devices in the drying bin can help reduce drying problems. They increase airflow and therefore reduce the static pressure the fan must work against. If the fan can move enough cfm of air per bushel, it can also allow you to dry more than a 6-foot depth of rice. Stirring devices also reduce the chance of overdrying the bottom layers in the bin. Caution: Stirring devices that are rough or have weld flux spots may damage rice by removing hulls. Check stirring devices daily to see if they have shifted or are damaging grain. Never place rice above the flighting on stirralls, which will cause mechanical damage to grain.

Layer Drying with Heated Air

To layer dry, place rice 4 feet deep in the bin as though it were going to be batch dried. Force heated air through the rice layer until the moisture content reaches 16 percent. Then, add 2- to 2 ½-foot layers of rice. Continue drying. As the rice layers are added, the airflow rates will decrease, causing the top rice layers to dry very slowly. At this point, if enough heat is added to reduce the relative humidity below 60 percent, the bottom layer will overdry. However, you can overcome this problem by layer-drying to a moisture content of 15 percent or less and a depth of only 10 feet in two different bins. You can combine the grain from these two bins in one and continue drying at a rate of about 0.5 to 1.0 cfm per bushel with a relative humidity of 60 percent. If there is a stirring device in the second bin, you can use normal drying procedures until all of the rice is dried and the second bin is full. When drying with only one bin, a stirring device is extremely helpful.

CAUTION: Avoid placing higher-moisture rice on top of lower-moisture rice. Establish a moisture range when filling a bin by placing the rice of higher moisture content on the bottom and the rice of lower moisture content on top. When placing rice of different moisture content in the same bin for drying, use a moisture range of 2 percent difference as a rule of thumb.

Bin Drying with Unheated Air

You may use unheated air to dry rice if you manage airflow properly. Rice dried this way has a superior milling quality.

The main limit of this method is that it depends on weather conditions. Bin drying with unheated air is not recommended for drying rice with a moisture content higher than 20 percent. When using this method, place the grain in the bins in layers, as in layer drying. Maintain air movement of at least 4 cfm per bushel when the moisture content is above 20 percent, 2 to 3 cfm per bushel when moisture content is 16 to 20 percent, and 1 cfm per bushel when moisture content is less than 16 percent.

Move air through the rice continuously until it reaches a 15 percent moisture content. After this point, run the fans only when the humidity is 65 percent or less, unless there has been a long period of wet weather and the temperature of the rice has risen. If wet weather continues for a long time, you may have to install a small heater in front of the fans to add about 5 °F. In most instances, this amount will reduce the humidity so some drying will occur in wet periods.

The longer you store rice at a moisture content higher than 13 percent, the higher the risk of spoilage. Generally, after the rice is dried to a moisture content of 15 percent, operate fans only during the day between 10 a.m. and 5 p.m.

When the rice is dried to a moisture content of 12.5 to 13 percent throughout the entire storage depth, fill the storage bin level with the eaves. Do not pile rice to a higher depth in the center. Over the next few weeks when the humidity is 60 to 65 percent and the air is 50 to 60 °F, force a small amount of air through the rice (aerate) to cool the rice kernels. Cool the kernels to 50 °F or less. Do not operate fans when the outside air temperature is below 32 °F.

When the grain is about 50 °F, probe it at least once a week for moisture and temperature variations. Pay close attention to the top center layer of the rice in the bin, because this is usually the first place moisture movement will occur. Extremely cold weather followed by mild or warm weather will often cause moisture movement to the top center layer.

If you find an increase in moisture or temperature in this or other areas, use the fan to cool. You can also move rice from one bin to another to mix it and correct the problem. If you don’t correct these problems, rice will spoil.

Aerate during storage when there is a difference of up to 10 °F between the temperature of the rice and the average outside temperature. Aeration will help bring the temperature of the rice and the outside temperature closer together. This is especially important as the average daily temperature begins to increase in the spring and summer. Once aeration begins, run the fan until the temperature in the entire rice bin has changed. In aeration, as in drying, a temperature or drying zone moves through the rice, up or down, in the direction the air is moving. If the drying or temperature zone is stopped before the job is completed, heating will develop in the zone. Grain located in the zone will soon spoil if you don't correct the situation.

Adjust the humidistat and thermostat so the aeration fan will run only when the outside conditions are right. This step will keep moisture from being added to the rice by the outside air. The amount of air a drying fan can deliver depends on the resistance to airflow, or static pressure, it must work against. As rice depth increases, static pressure also increases, decreasing airflow per bushel. Always operate the fans within the limitations of the system to achieve acceptable aeration and drying. The amount of time the fan must run to change the temperature of stored grain depends on how much air is circulated through the grain. Estimated fan running times required for various quantities of air per bushel to change the temperature of stored grain are listed in the following table.

Quantity of Air	Time to Change
(cfm per bushel)	(hours)/A)
0.1	140
0.2	80
0.3	65
0.4	50
0.5	45
1.0	30
5.0	11

Suggested Steps for On-Farm Rice Drying

1. Adjust harvesting equipment to clean foreign material from the rice.
2. Determine rice moisture content for each truck or grain cartload as the rice is put in the bin.
3. Place rice that is harvested first in the drying bin 4 to 6 feet deep. The depth of the rice depends on its initial moisture content and the capabilities of the fan.

   Air Flow (cfm) per bushel needed:
   less than 15 percent = 1 cfm per bushel
   15 to 18 percent = 2 cfm per bushel
   18 to 20 percent = 3 cfm per bushel
   20 to 22 percent = 4 cfm per bushel
   more than 22 percent = 6 cfm per bushel

4. Level rice across the entire drying bin for uniform air pressure and airflow.
5. Open air exits so air can exhaust easily from the drying bin.
6. Turn on the fans as soon as the perforated floor is covered with 1 foot or more of rice.
7. Do not hold wet rice in a bin, truck, combine, hopper, or grain cart longer than 12 hours without moving air through the container to cool the rice.
8. Measure the relative humidity and temperature of the outside air to determine the maximum temperature setting of the heater.

   When the relative humidity is
   less than 40 percent, add no heat
   40 to 55 percent, add 5 °F
   55 to 75 percent, add 10 °F
   more than 75% percent, add 15 °F

9. Use the above information as a guide to estimate the temperature rise when the moisture content of the rice is greater than 15 percent. Never exceed an air temperature of 100 °F. The ideal temperature is 90 to 95 °F. Temperatures above 100 °F can lead to stressed rice grains.
10. Dry batches of rice until the moisture content is 15 percent or less.
11. Remember that batch drying time is affected by six factors: cubic feet per minute (cfm) of air per bushel, temperature difference between the rice and the air entering the rice, current moisture content of the rice, original moisture content of the rice, depth of the rice, and air flow resistance. It would take about 72 hours to dry rice from 22 to 15 percent moisture, assuming a temperature drop of 10 °F at 6 cfm per bushel.
12. If necessary, reduce drying time by increasing airflow from 6 cfm per bushel to 8 or 10 cfm per bushel. Do not heat airflow more than 10 °F above the outside air temperature.
13. After the rice has reached 15 percent moisture content, move it to another bin. You can increase the depth in the new bin because the airflow per bushel will be decreased. To continue drying, control the relative humidity so it is between 60 and 65 percent until the rice moisture content is 12.5 to 13 percent.
14. Use a stirring device to avoid overdrying the bottom rice layers in the final drying bin. The moisture content of the bottom layer, where stirring is not possible, will be 10 to 11 percent. The top layer will have increased to about 17 percent. When two-thirds of the rice in the bin is below 13 percent, move the rice to another bin, where the top and bottom layers will be mixed. Once you have done this, continue forcing 60 to 65 percent relative humidity air through the rice until all of the rice is dry.
15. Use a stirring device to reduce the static pressure the fan must work against. Rice deeper than 6 feet can be batch-dried by using a stirring device if the fan can move enough cfm of air per bushel. A stirring device will reduce the risk of overdrying the bottom layers while the top layers are being dried.
16. Fill the storage bins level with the eaves when the moisture content of the rice is 12.5 or 13 percent through the entire storage depth. Do not pile rice in the center.
17. Aerate grain kernels for the next few weeks when the humidity is about 60 to 65 percent and the air is about 50 °F to 60 °F.
18. Do not operate fans when the outside air temperature is cooler than 32 °F. Cool the grain to 50 °F or less.
19. After the grain is approximately 50 °F, probe the grain at least once a week for variations in moisture or temperature. Also check for insects.

20. Monitor the center top rice layer in the bin closely. Normally, moisture will move to the top layer first. If there is any indication that moisture or temperature is increasing in this or other areas, either turn the fans on or mix the rice by moving it from one bin to another. Check weekly and after each rain or snow around vents, manholes, doors, and bin top for leaks and spoiled rice.
21. Do not mix any spoiled rice on the top layer with good rice on the bottom. Mixing good rice with spoiled rice will downgrade all of the rice. Remove and discard spoiled rice from the bin. Never allow stirralls to operate unless you are absolutely sure there is no spoiled rice within a bin.
22. During the storage period, notice extreme temperature changes. If a period of extremely cold weather is followed by warm or mild weather, moisture movement may occur, usually at the top layer toward the center. In this situation, aerate rice to prevent spoilage.
23. For more information, see your county Extension agent.

Insect Pests of Stored Rice

To maintain good quality rice during storage, protect it from insect attack. Insects that may attack rice in storage include the Angoumois grain moth, confused flour beetle, and rice weevil.

Angoumois Grain Moth

The front wings of this insect are buff and have no distinguishing marks; the back wings are gray. The back edge of each wing has a long fringe. Adult females may lay as many as 150 eggs individually or in clusters of about 20. The caterpillar bores into a rice kernel after emerging from the egg and remains there until fully developed. Grain infested with this insect may develop a bad smell and taste that ruin its usefulness.

Rice Weevil

This insect is usually found along with the granary weevil, and damage associated with these insects is identical. The rice weevil is dark brown or nearly black and has ridged wing covers. Each wing cover has two yellowish spots. The granary weevil looks similar but is somewhat larger and does not have the yellowish spots on its wing covers. The female rice weevil hollows out small cavities in kernels of grain and lays eggs in them. Under optimum conditions, 300 to 400 eggs are deposited. The grub will develop to maturity within the kernel. A field infestation of rice weevils can lead to storage problems.

Confused Flour Beetle

The adult confused flour beetle is slim, about ⅛ inch long, and a uniform reddish brown to black. Female beetles lay eggs either in cracks or on the grain. The young larvae feed on broken rice kernels and trash in the rice. Both adults and larvae can be found crawling around in infested grain. Infestation often occurs as the result of improperly cleaned bins or excess trash in the rice.

Controls

To protect grain from insects, follow a good sanitation program. Remove grain debris and refuse from the bin. Pay attention to cracks, crevices, areas behind partitions, floors, and outside areas. Remove refuse from the bin area. Do not store new grain on a bed of old grain. Infestations may be carried into the storage bin from infested grain accumulating in grain buggies, augers, or combines. Clean equipment carefully.

After completing the sanitation program, apply a residual insecticide to the storage bin. Spray all surfaces until wet. Give particular attention to cracks and crevices where insects may hide. Spray around the outside of the bin. If there is a clearance under the bin, spray it. To give insects enough time to come in contact with the insecticide, spray 2 to 3 weeks before harvest. Before storing, sweep again to remove all dead insects.

You can spray with a 3-gallon, compressed-air garden sprayer, depending on the size of the facility. Adjust sprayer for a coarse, wet spray. Mix 3 gallons of water with 1 pint of 57 percent Cythion (malathion) E.C. or 1 quart of 25 percent methoxychlor E.C. or 1 pound 50 percent methoxychlor W.P. Three gallons of spray should cover about 1,500 square feet.

Do not overlook storage conditions as a way to prevent insect damage. Insect development depends upon a temperature of at least 60 °F and a moisture content greater than 12 percent. The quicker you can reduce the temperature of the grain mass to 60 °F or below, the better; 50 °F or less is ideal. This also helps maintain good quality rice during storage.

If stored grain becomes infested with one or more of the previously mentioned insects, call a professional to fumigate the infested bins.

Use only those insecticides cleared for use on rice, and use them at the proper rate. Remember, stored grains are monitored for illegal residues by several governmental agencies. More information is available on insect control for stored grain from Extension Publication 915, Stored Grain Insect Control, available at your county Extension office.

How To Determine Bushels of Rice in a Storage Bin

You can determine the number of bushels of rice stored in a bin using the cubic foot method or the cubic inch method. Use these formulas, constants, and conversion factors:

1. V = volume in cubic feet or cubic inches.
2. π = pi = 3.1416, a constant factor used in volume calculations.
3. d = diameter, the straight line distance measured through the center of the bin from one side to the other side. Units may be in feet or inches.
4. r = radius, a straight line distance in feet or inches from the center of the bin to the inside wall of the bin. Radius is equal to ½ the diameter (r = ½ d).
5. h = height, the distance in feet or inches from the floor of the bin (bottom of the rice) to the top of the grain level in the bin.

One bushel of rice = 1.244 cubic feet or 2149.632 cubic inches. These factors are also constants used in the following calculations:

Formula: $V = \pi r^2 \times h$

Calculation Examples:

Let's say you have a bin with a diameter of 30 feet. The radius (r) is one-half the diameter (d), so $r = 30/2 = 15$ feet. The radius is 15 feet. The depth of rice in the bin is 20 feet, which is the height (h).

The following constants are known:

$\pi = 3.1416$
r = 15 feet
h = 20 feet

These factors can be substituted into the formula:

$V = \pi r^2 h$

and the volume in cubic feet of rice in the bin can be determined:

$V = (3.1416)(15)^2(20)$
$V = 3.1416 \times 225 \times 20$
V = 14137.2 cubic feet of rice in the bin

There is a total of 14,137.2 cubic feet of rice in the bin. To determine how many bushels of rice this is, divide the 14,137.2 cubic feet by the constant 1.244 cubic feet per bushel. This is the cubic feet space occupied by one bushel or rice.

Therefore, bushels of rice in bin

$$= \frac{\text{Volume in cubic feet of rice in bin}}{\text{Volume in cubic feet occupied by one bushel of rice}}$$

Bushels of rice in bin

$$= \frac{\text{14,137.2 cubic feet of rice in bin}}{\text{1.244 cubic feet of rice occupied by one bushel of rice}}$$

Bushels of rice in bin = 11,364

About 11,364 bushels of rice are in the storage bin. You can make the same calculations if you use inches instead of feet. Using the same formula and applying the appropriate constants given, here are the calculations (See Figure 11.1):

The following is known:
π = 3.1416 (constant)
r = 180 inches (180 inches = 15 feet)
h = 240 inches (240 inches = 20 feet)

$V = \pi r^2 h$
$V = (3.1416)(180)^2(240)$
V = 3.1416 X 32,400 X 240
V = 24,429,081.6 cubic inches of rice in bin

Bushels of rice in bin

$$= \frac{\text{Volume in cubic inches of rice in bin}}{\text{Volume in cubic inches occupied by one bushel of rice}}$$

Bushels of rice in bin

$$= \frac{24{,}429{,}081.6 \text{ cubic inches of rice in bin}}{2149.6 \text{ cubic inches occupied by one bushel of rice}}$$

Bushels of rice in bin = 11,364

If you do not know the diameter or radius of the grain bin, you can figure it out. Begin by measuring the outside circumference of the bin wall with a measuring tape. See Figure 11.1.

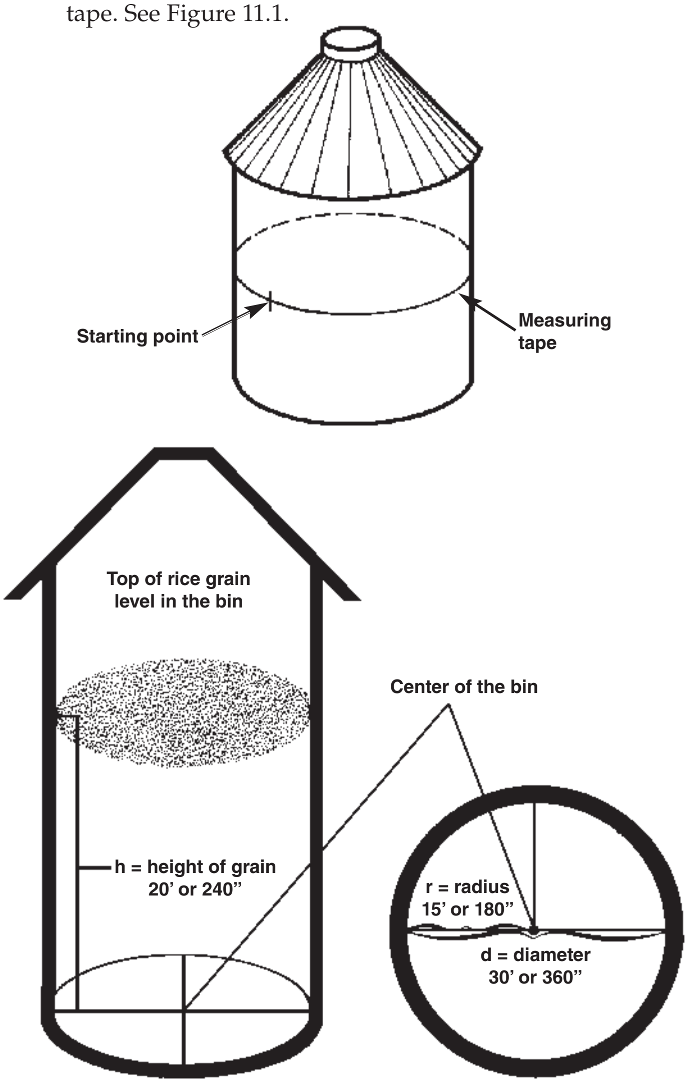


Figure 11.1. Illustration of measuring and determining grain bin capacity

This method is not as accurate as a diameter or radius measurement made inside the grain bin unless you can subtract the thickness of the grain bin metal from the diameter calculated from the grain bin circumference measurement.

Let's say the outer circumference of the bin measured 99 feet. The formulas:

$$d \text{ (diameter)} = \frac{\text{Circumference of the bin}}{\pi}$$

$$\text{and } r \text{ (radius)} = 1/2\ d \text{ (diameter)}$$

can then be used to determine the radius, which can be used in the above calculations.

$$\text{So:}\quad d = \frac{99 \text{ feet (circumference of the bin)}}{3.1416}$$

$$d = 31.51 \text{ feet}$$

$$r = \frac{31.51 \text{ feet (diameter)}}{2}$$

$$r = 15.76 \text{ feet}$$

Table 11.1 gives multipliers appropriate for specific moisture contents. You can use these multipliers in simple calculations to determine the number of bushels of dry rice (12 percent moisture content) on hand.

The following example shows how to use the table. It uses the answers from the sample problem on the previous pages.

We have already determined that the storage bin held about 11,364 bushels of rough rice. Let's say we got a moisture content sample from the bin, and it contained 14 percent moisture. Therefore, the storage bin contains 11,364 bushels of rice with a moisture content of 14.0 percent. When the rice is standardized down to a moisture content of 12.0 percent, how many bushels of rice will be in the storage bin?

By using the multiplier for 14.0 percent moisture, you can make the following calculations:

Bushels of rice at sampled moisture content x appropriate multiplier = bushels of rice at 12 percent moisture.

11,364 x 0.97727 (multiplier for 14 percent moisture) = 11,105.998 or 11,106 bushels of rice at 12 percent moisture.

Consequently, 11,106 bushels of rice with a moisture content of 12% would be in the bin.

Table 11.1. Moisture Reduction Table (Multiply Yields by Appropriate Factor).

Moisture Content	Multiplier	Moisture Content	Multiplier	Moisture Content	Multiplier	Moisture Content	Multiplier
7.0	1.05682	11.1	1.01023	15.2	0.96364	19.3	0.91704
7.1	1.05568	11.2	1.00909	15.3	0.96250	19.4	0.91591
7.2	1.05455	11.3	1.00795	15.4	0.96136	19.5	0.91477
7.3	1.05341	11.4	1.00682	15.5	0.96023	19.6	0.91363
7.4	1.05227	11.5	1.00568	15.6	0.95909	19.7	0.91250
7.5	1.05114	11.6	1.00455	15.7	0.95795	19.8	0.91136
7.6	1.05000	11.7	1.00341	15.8	0.95682	19.9	0.91022
7.7	1.04887	11.8	1.00227	15.9	0.95568	20.0	0.90909
7.8	1.04773	11.9	1.00114	16.0	0.95454	20.1	0.90795
7.9	1.04659	12.0	1.00000	16.1	0.95341	20.2	0.90682
8.0	1.04546	12.1	0.99886	16.2	0.95227	20.3	0.90568
9.1	1.03296	12.2	0.99773	16.3	0.95113	20.4	0.90454
8.2	1.04318	12.3	0.99659	16.4	0.95000	20.5	0.90341
8.3	1.04205	12.4	0.99545	16.5	0.94886	20.6	0.90227
8.4	1.04091	12.5	0.99432	16.6	0.94773	20.7	0.90113
8.5	1.03977	12.6	0.99318	16.7	0.94659	20.8	0.90000
8.6	1.03864	12.7	0.99205	16.8	0.94545	20.9	0.89886
8.7	1.03750	12.8	0.99091	16.9	0.94432	21.0	0.89772
8.8	1.03636	12.9	0.98977	17.0	0.94318	21.1	0.89659
8.9	1.03523	13.0	0.98864	17.1	0.94204	21.2	0.89545
9.0	1.03409	13.1	0.98750	17.2	0.94091	21.3	0.89431
9.1	1.03296	13.2	0.98636	17.3	0.93977	21.4	0.89318
9.2	1.03182	13.3	0.98523	17.4	0.93863	21.5	0.89204
9.3	1.03068	13.4	0.98409	17.5	0.93750	21.6	0.89091
9.4	1.02955	13.5	0.98295	17.6	0.93636	21.7	0.88977
9.5	1.02841	13.6	0.98182	17.7	0.93523	21.8	0.88863
9.6	1.02727	13.7	0.98068	17.8	0.93409	21.9	0.88750
9.7	1.02614	13.8	0.97954	17.9	0.93295	22.0	0.88636
9.8	1.02500	13.9	0.97841	18.0	0.93182	22.1	0.88522
9.9	1.02386	14.0	0.97727	18.1	0.93068	22.2	0.88409
10.0	1.02273	14.1	0.97614	18.2	0.92954	22.3	0.88295
10.1	1.02159	14.2	0.97500	18.3	0.92841	22.4	0.88181
10.2	1.02046	14.3	0.97386	18.4	0.92727	22.5	0.88068
10.3	1.01932	14.4	0.97273	18.5	0.92613		
10.4	1.01818	14.5	0.97159	18.6	0.92500		
10.5	1.01705	14.6	0.97045	18.7	0.92386		
10.6	1.01591	14.7	0.96932	18.8	0.92272		
10.7	1.01477	14.8	0.96818	18.9	0.92159		
10.8	1.01364	14.9	0.96704	19.0	0.92045		
10.9	1.01250	15.0	0.96591	19.1	0.91932		
11.0	1.01136	15.1	0.96477	19.2	0.91818		

Bushel = 45 lbs or 0.45 cwt; Barrel = 162 lbs or 3.6 bushels; 1 cwt = 2.2 bushels

Rice Quality

Rice quality begins at seedbed preparation, seed selection, and seeding. Some requirements for high-quality rice are a firm, well-prepared, weed-free seedbed; rice seed free of red rice; uniform emergence; good herbicide coverage of weeds; and red rice control. Uniform emergence develops into uniform maturity. Uniform maturity gives a narrower range of grain moisture at harvest, which favors high whole-grain milling quality.

When considering objectionable seeds, control broadleaf weeds early preflood when they are less than 2” tall. Afterwards, flood within 3 to 5 days to prevent reinfestation. Do not depend on being able to make a timely application of a phenoxy-type herbicide later. It would be better to do this as a backup if needed. With today’s herbicides, there’s no reason to allow hemp sesbania seed to discount rice.

Test Weight or Cup Weight

Test weight reflects weight per bushel volume (1 bu = 1.244 ft^3 or 1 bu = 45 lbs). Test weight is lowered by foreign material, blanks or empty hulls, lightweight immature grains, shelled grains, weed seeds, and other factors. Rice that is lighter because of blanks and trash is likely to yield less milled rice per pound of rough rice. Blanks, trash, and immature grains are lost in the milling process. Extensive shelling increases test weight but lowers whole grain quantity because of mechanical breakage during threshing. The most favorable weights are 44 to 46 pounds; 42 to 43 pounds is average; 41 pounds or below is poor.

Grain Maturity Stress

Environment and disease complexes affect rice kernels when they develop under unfavorable conditions and produce kernels more susceptible to breakage. Rice kernels break easily with minimum mechanical pressure when they develop under stress. You can easily detect degrees of rice grain stress, even at 16 to 20 percent moisture, by removing the hulls mechanically. Here are some factors that can cause rice grain stress:

- Insufficient flooding may allow the plant too little moisture to complete grain formation and development.
- Draining fields before grains low on the panicle mature to the dough stage can result in soil moisture stress, especially when additional rainfall does not occur.
- Recently land-formed fields that lack the proper nutrient balance for rice to complete maturing on heavy cut areas results in rice vegetation’s dying early, before grain is fully developed. Fill areas in fields result in rice plants’ remaining green and healthy and developing large, mature grains.
- The flow of moisture and nutrients for grain formation and development is critical during the heading stage. Plant injury that reduces or stops this movement before grain maturity reduces yield and quality. Disease may invade the lower stalk, stem, or head before maturity. The vegetation portion of plants dies or becomes severely injured, causing stress by reducing the nutrients and water supply to maturing kernels. Late-maturing rice may be more affected by diseases, especially blast and stem rot, than early-maturing rice is.
- Extended cool night temperatures of 56 °F and below during the grain formation stage can cause sterility, which will produce a zone or area of blanks in the rice head, depending on the developmental stage of the head. Sudden drops in temperature cause plant stress.
- Humidity of only 20 to 30 percent accompanied by wind during maturation causes grain to dry too quickly in the field before harvesting, resulting in stress cracks. When rice dries, moisture moves from the inner to the outer portion of the grain. Rapid drying causes the outer portion of the grain to dry faster than the inner portion can keep up. Excessive drying in the outer portion of the grain causes it to shrink so that it no longer fits the inner portion. The outer portion then cracks. The same thing happens in grain-drying facilities when the grain is dried too rapidly.

Moisture Level at Harvest

Ideal moisture level at harvest is between 16 and 20 percent, which promotes maximum milling yield. Lower moisture levels can reduce milling yield, especially for current hybrids.

Shelled Grains and Mechanical Damage

Shelling rice while harvesting breaks the grain. It is ideal to have less than 3 percent shelled rice. Generally 5 percent shelled rice reduces whole grain milling quality by 3 percent, or about $0.08/bu. Grain with 8 to 10 percent shelled rice reduces whole grain milling quality by about $0.19/bu. A 2 ½-inch circle of a single layer of rough rice is about 100 kernels. The average count in several circles will provide the percent of shelled grain or degree of mechanical damage.

Drying Stress

Avoid drying rice at high temperature and high volume of air. The rapid removal of moisture stresses rice and may break, or check, grains. Use the proper volume of air and temperature when drying rice to keep from stressing the rice grain. When deciding rate of airflow, take into account the volume of grain in the bins.

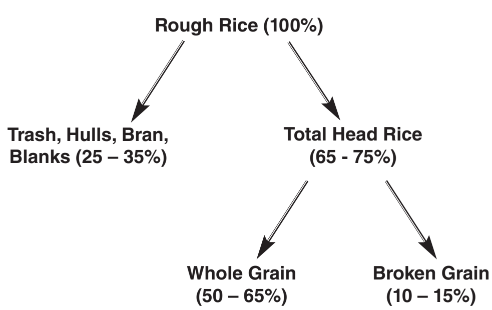
Uniform Moisture Level after Drying

Rice mills best when it falls within a uniform moisture level of 11.5 to 12.5 percent. When grain within a bin has a wide range of moisture, it is more likely to break when milled, even if the average moisture is 12.5 percent.

Milling Yield

Milling yield is expressed in terms of percentage whole versus percentage broken kernels of milled rice. You can also think of this estimate as a breakdown of 100 lbs of rough rice.

Milled yield is estimated in the following figure.



When determining the price of rice per a bushel, milling yield is very important. The more total head rice per bushel, the higher the price per bushel. Broken kernels are only worth half of what whole kernels are worth. Table 11.2. shows the current loan value for whole and broken kernels.

Table 11.2. Current loan value of whole and broken kernels.

		Loan Value
Whole Grain	3/4 original length or longer	$0.1052/lb
Broken Grain	Less than 3/4 original length	$0.0526/lb

Example Scenarios

Scenario 1: 100 lb rough rice with one or more of the following problems: lots of trash and blanks, low moisture at harvest, high percentage of grains shelled during harvest, stressed during development

100 lbs rough rice - 33 lbs hulls, bran, trash, blanks = 67 lbs total milled rice

Milling yield: $^{50}/_{67}$

50 (head rice or whole grain) x 0.1052 = $5.26

17 (broken) x 0.0526 = $0.89

Rice per cwt (100 wt) = $6.15

Convert cwt to bu x 0.45

Price per bushel = $2.77 loan value

Scenario 2: 100 lbs clean rice harvested at 12 to 20 percent with little or no shelling, dried slowly and uniformly, no apparent grain maturity stress, and well-developed kernels

100 lbs - 29 lbs hulls, bran = 71 lbs total milled rice

Milling yield: $^{60}/_{71}$

60 (head rice or whole grain) x 0.1052 = $6.31

11 (broken) x 0.0526 = $0.58

Rice per cwt (100 wt) = $6.89

Convert cwt to bu x 0.45

Price per bushel = $3.10 loan value

If you subtract $2.77 (the price per bushel of the rough rice in scenario 1) from $3.10 (the price per bushel of the clean rice in scenario 2), you find that the clean rice is worth $0.33 more per bushel. Assuming each acre yields 150 bushels in both scenarios, that $0.33 difference makes a difference of **$49.50 per acre because of quality alone.**

Grain Temperature after Drying

After rice has been dried to a moisture content of 12.5 to 13.0 percent, aerate it to a temperature of 45 to 50 °F when the relative humidity is 60 percent or less. This tempers the stored rice, increasing whole grain milling quality and conditioning it for cold winter temperatures. Warm rice and cold outside temperatures promote condensation inside the bin, and moisture like condensation causes rice to lose quality. Also, cooled rice helps keep insect eggs from hatching, which can prevent some insect problems.

Heat-Damaged Kernels after Drying

High-moisture grain stored in temperatures of 100 to 135 °F may be stained dark. Proper drying and aeration help prevent these stains.

Red Rice

The most serious loss is yield loss from competition and lodging because many of the grains fall off the head onto the ground, or shatter, before harvest. These fallen grains compound production problems in future rice crops. However, discounts are given during the grain grading process, as listed in the table that follows.

Others

Keep glass and treated seed away from grain bins and grain carts. This contamination condemns rice for human consumption. Rice quality demands timely management of practices we can control. Other elements that affect yield and quality but cannot be controlled remain the major challenge to the rice industry.

USDA Rice Grades

Table 11.3 gives the discounts associated with USDA grades. Table 11.4 gives the USDA grades and grade requirements. Table 11.5 gives the discounts for smut-damaged rice.

Table 11.3. USDA Grade discounts..

USDA Grade Basis	Discount ($/Bu)
1 & 2	
3	$0.135
4	$0.270
5	$0.450
6*	$0.900
Sample grade*	$2.475

*** Discounts for rice grades US No. 6 and Sample grade should be used for special rice loans and farm-stored rice loans delivered to CCC or buyers.**

Table 11.4. USDA grades and grade requirements for classes of rough rice.								
	Maximum Limits of							
	Seeds and Heat Damaged Kernels				Chalky Kernels[ab]			
Grade	Total Singly or Combined	Heat Damaged Kernels and Objectionable Seeds Singly or Combined	Heat Damaged Kernels	Red Rice Damaged and Kernels Singly or Combined	In Long Grain Rice	In Med. or Short Grain Rice	Other Types[c]	Color Requirements Minimum
	Number in 500 grams	Number in 500 grams	Number in 500 grams	%	%	%	%	
U.S. No. 1	4	3	1	0.5	1.0	2.0	1.0	White or creamy
U.S. No. 2	7	5	2	1.5	2.0	4.0	2.0	May be slightly gray
U.S. No. 3	10	8	5	2.5	4.0	6.0	3.0	May be light gray
U.S. No. 4	27	22	15	4.0	6.0	8.0	5.0	May be gray or slightly rosy
U.S. No. 5	37	32	25	6.0	10.0	10.0	10.0	May be dark gray or rosy
U.S. No. 6	75	75	75	15.0[d]	15.0	15.0	10.0	May be dark gray or rosy

U.S. Sample grade is rough rice that (a) does not meet the requirements for any of the grades from U.S. No. 1 to U.S. No. 6, inclusive; (b) contains more than 14.0% moisture; (c) is musty, sour, or heating; (d) has any commercially objectionable foreign odor; or (e) is otherwise of distinctly low quality.

[a]For the special grade Parboiled Rough Rice. Parboiled Rough Rice is rough rice in which the starch has been gelatinized by soaking, steaming, and drying. Grades U.S. No. 1 to U.S. No. 6, inclusive, contain no more than 10.0% ungelatinized kernels. Grades U.S. No. 1 and U.S. No. 2 contain no more than 0.1%; grades U.S. No. 3 and U.S. No. 4, no more than 0.2%; and grades U.S. No. 5 and U.S. No. 6, no more than 0.5% of nonparboiled rice. If the rice is (1) not distinctly colored by the parboiling process, it is considered "Parboiled Light"; (2) distinctly but not materially colored by the parboiling process, it is considered "Parboiled"; (3) materially colored by the parboiling process, it is considered "Parboiled Dark" The color levels for "Parboiled Light," "Parboiled," and "Parboiled Dark" rice shall be in accordance with the interpretive line samples for parboiled rice.

[b]For the special grade Glutinous Rough Rice. Glutinous rough rice is special varieties of rice (*Oryza sativa L. glutinosa*) that contain more than 50% chalky kernels. Grade U.S. No. 1 contains no more than 1.0% nonchalky kernels; grade U.S. No. 2, no more than 2.0% nonchalky kernels; grade U.S. No. 3, no more than 4.0% nonchalky kernels; grade U.S. No. 4, no more than 6.0% nonchalky kernels; grade U.S. No. 5, no more than 10.0% nonchalky kernels; and grade U.S. No. 6, no more than 15.0% nonchalky kernels.

[c]These limits do not apply to the class Mixed Rough Rice.

[d]Rice in grade U.S. No. 6 contains no more than 6.0% damaged grain.

Table 11.5. Discounts for smut-damaged rice.

Smut Damage Percent	Discount ($/bu)
0.1 - 1.0	0.0225
1.1 - 2.0	0.0450
2.1 - 3.0	0.0675

Note: Rice containing more than 3% smut is called "smutty" rice. It is considered low-quality rice, which qualifies for loan at 20% of the discounted loan value.

Rice Economics

CHAPTER 12

Steve Martin

Budgeting and Cultivar Comparisons

Mississippi rice producers have enjoyed consistent yield increases over the last several years (Figure 12.1). The increases in yield can be attributed at least in part to new cultivars. Delta rice producers can now choose from several rice cultivars. The cultivars differ in terms of rough rice yields, milling yields, susceptibility to diseases, straw strength, and herbicide tolerance. Our standard planning budgets are shown in Tables 12.1 and 12.2. Tables 12.3 through 12.8 show costs of production estimates, value per bushel estimates, and returns per acre for selected cultivars based on data from our variety trials.

Value per bushel is based on loan rate calculations of $10.66 per hundredweight for whole grains and $5.33 per hundredweight for broken grains (assumes $6.66/cwt for 55/70 milling).

Rough rice yields and milling percentages are from MSU on-farm variety trials. The data is a 3-year average for Clearfield 161, Cocodrie, Priscilla, and Wells. Clearfield XL8 Hybrid is a 2-year average. Cheniere, Francis and XP710 are 1 year only.

Direct and fixed costs are calculated using the Mississippi State Budget Generator (MSBG) and follow the general framework and procedures defined in the MSBG program (Laughlin and Spurlock). The MSBG is the program used for all the planning budgets for Mississippi State and several other states. Direct costs are those costs associated with actually producing the crop. Fixed costs per acre are the costs associated with owning farm machinery and equipment. Total specified costs per acre are the sum of direct and fixed costs. These costs are called "specified costs" because they represent only the costs specified in the budget. The specified costs in these budgets do not include land costs, general farm overhead, or any returns to management.

In order to standardize this analysis, it was based on a "worst case" scenario. The cost of a fungicide treatment was added to the cost of producing a cultivar rated very susceptible to a disease. The cost of a fungicide was not added to all cultivars rated susceptible based on the history of that variety. Every farm is different, and disease and insect pressure varies by field. All pesticide treatments would not have to be made in every situation, as assumed in this analysis. Not all cutivars will require an insecticide application each year, and the cost of production varies depending upon location and weather. Consider your own unique situation. The cost of draining Cocodrie for straighthead was not included, although it is rated very susceptible. Draining is necessary if Cocodrie is grown on lighter soils but is generally not necessary on heavy, clay soils.

Table 12.3 presents cost of production estimates for each of the nine rice cultivars included in this analysis. The second column shows direct costs per acre; the third column, fixed costs per acre; and the fourth column, total specified costs per acre.

Based strictly on cost of production estimates, Priscilla appears to have an advantage. The hybrid lines, Clearfield XL8 and XP710, are the most expensive to produce. The other cultivars are grouped closely together in terms of cost of production. Note that the cost estimates of production include a cost for hauling rice ($0.10 per bushel) and a cost for drying rice ($0.40 per bushel). Cultivars with higher yields incur higher costs in these categories. Tables 12.4 through 12.6 further explain the methods for determining production costs for the rice cultivars.

Table 12.4 compares direct expense items for each cultivar. When considering Tables 12.4, also consider Tables 12.5 and 12.6. Table 12.5 shows estimated fungicide applications and the cost of those applications. The fungicide applications shown are based on a "worst-case" scenario.

Table 12.6 shows estimated insecticide applications and the costs of those applications. Again, this is based on a worst-case scenario, and you should consider your own situation. As Table 12.6 shows, all cultivars are susceptible to both stinkbug and rice water weevil damage, so these insecticide costs are equal across all cultivars. Including these costs does affect the returns over costs shown in Table 12.8.

Other major differences in cost of production are in the herbicide, fertilizer, hauling, and drying categories. Again, those cultivars with higher rough rice yields are more expensive to haul and dry.

Table 12.7 shows rice yield, milling percentages, and value per bushel. Rice prices above loan value might change this portion of the analysis. Also, loan deficiency payments (LDP) or marketing premiums above loan could increase value per bushel. Most often these premiums or LDP's are on a rough rice basis, which favors higher-yielding cultivars.

When calculated at loan value, Cheniere provides the highest returns per bushel. Cocodrie and Clearfield 161 follow closely. Francis, followed by Priscilla and Wells, provides the lowest returns per bushel.

Table 12.8 shows returns above costs for each of the rice cultivars. Total returns are given in column two and are calculated based on the value per bushel and rough rice yield data given in Table 12.7. The third and fourth columns of Table 12.8 give returns above direct costs and returns above total specified costs. These costs are calculated based on the total returns given in the second column and the costs of production estimates given in Table 12.3. XP710 and Cheniere provide the highest total returns per acre. Clearfield 161 had the lowest returns per acre. However, if red rice is a problem, Clearfield 161 may fit in your program. Given the cost of production shown in Table 12.3, Cheniere, followed by XP710, provides the highest per-acre returns above total costs.

An interesting part of this analysis is the comparison of value per bushel and total returns. The cultivars that produced higher values per bushel based on milling grade produced some of the lowest total returns because they had lower yields of rough rice. Under the pricing structures used in this analysis, rough rice yield is very important. Remember that loan deficiency payments (LDP) and some marketing premiums might be paid on a rough-rice basis.

Table 12.1 Summary of estimated costs and returns per acre
Contour Levee Rice Flood irrigated, 33 ac-in., Delta Area, Mississippi, 2007

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		dollars
INCOME				
Rice	bu	4.32	140.0000	604.80
TOTAL INCOME				604.80
DIRECT EXPENSES				
CUSTOM SPRAY	acre	13.50	1.0000	13.50
GIN/DRY	acre	56.00	1.0000	56.00
FERTILIZERS	acre	79.25	1.0000	79.25
FUNGICIDES	acre	9.23	1.0000	9.23
HERBICIDES	acre	54.87	1.0000	54.87
INSECTICIDES	acre	6.00	1.0000	6.00
SEED/PLANTS	acre	22.05	1.0000	22.05
SERVICE FEE	acre	4.00	1.0000	4.00
ADJUVANTS	acre	0.74	1.0000	0.74
CUSTOM FERT/LIME	acre	22.50	1.0000	22.50
CUSTOM HARVEST/HAUL	acre	14.00	1.0000	14.00
HAND LABOR	hour	6.44	0.3356	2.17
IRRIGATE LABOR	hour	6.44	3.5250	22.69
OPERATOR LABOR	hour	9.41	0.8107	7.63
RICE MGT. LABOR	hour	6.44	1.5000	9.66
UNALLOCATED LABOR	hour	9.44	0.5824	5.50
DIESEL FUEL	gal	2.41	35.7040	86.04
REPAIR & MAINTENANCE	acre	20.75	1.0000	20.75
INTEREST ON OP. CAP.	acre	12.43	1.0000	12.43
TOTAL DIRECT EXPENSES				449.01
RETURNS ABOVE DIRECT EXPENSES				155.79
TOTAL FIXED EXPENSES				87.69
TOTAL SPECIFIED EXPENSES				536.70
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				68.10

Table 12.2 Summary of estimated costs and returns per acre
Straight Levee Rice Flood irrigated, 27 ac-in., Delta Area, Mississippi, 2007

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		dollars
INCOME				
Rice	bu	4.32	150.0000	648.00
TOTAL INCOME				648.00
DIRECT EXPENSES				
CUSTOM SPRAY	acre	13.50	1.0000	13.50
GIN/DRY	acre	60.00	1.0000	60.00
FERTILIZERS	acre	79.25	1.0000	79.25
FUNGICIDES	acre	9.23	1.0000	9.23
HERBICIDES	acre	54.87	1.0000	54.87
INSECTICIDES	acre	6.00	1.0000	6.00
SEED/PLANTS	acre	22.05	1.0000	22.05
SERVICE FEE	acre	2.00	1.0000	2.00
ADJUVANTS	acre	0.74	1.0000	0.74
CUSTOM FERT/LIME	acre	22.50	1.0000	22.50
CUSTOM HARVEST/HAUL	acre	15.00	1.0000	15.00
HAND LABOR	hour	6.44	0.3356	2.17
IRRIGATE LABOR	hour	6.44	2.3750	15.29
OPERATOR LABOR	hour	9.41	0.7292	6.87
RICE MGT. LABOR	hour	6.44	0.7000	4.51
UNALLOCATED LABOR	hour	9.43	0.5519	5.21
DIESEL FUEL	gal	2.41	29.9420	72.15
REPAIR & MAINTENANCE	acre	19.73	1.0000	19.73
INTEREST ON OP. CAP.	acre	11.61	1.0000	11.61
TOTAL DIRECT EXPENSES				422.68
RETURNS ABOVE DIRECT EXPENSES				255.32
TOTAL FIXED EXPENSES				103.74
TOTAL SPECIFIED EXPENSES				526.42
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				121.58

Table 12.3. Production costs per acre for selected rice cultivars.

Cultivar	Direct Costs per Acre	Fixed Costs per Acre	Total Specified Costs
Clearfield XL8	$456	$61	$517
Clearfield 161	$392	$58	$450
Cheniere	$380	$58	$438
Cocodrie	$373	$58	$431
Francis	$358	$58	$416
Priscilla	$323	$58	$381
Wells	$357	$61	$418
XP710	$411	$61	$472

***Specified costs do not include land charges, general farm overhead, or returns to management.**

***Costs and returns are based on 3-year averages except for Clearfield XL8, Cheniere, and XP710.**

Table 12.4. Per acre-direct cost comparison of selected rice cultivars. [This graph is also in IS1342]								
Direct Costs	**Clearfield XL8**	**Clearfield 161**	**Cheniere**	**Cocodrie**	**Francis**	**Priscilla**	**Wells**	**XP710**
Custom Spray (airplane)	$16	$24	$24	$24	$20	$16	$20	$16
Fungicides	$0	$43	$43	$43	$27	$0	$27	$0
Herbicides	$55	$55	$37	$37	$37	$37	$37	$37
Seed	$127	$35	$21	$21	$21	$21	$21	$89
Operator Labor	$15	$15	$15	$15	$15	$15	$15	$15
Unallocated Labor	$12	$12	$12	$12	$12	$12	$12	$12
Haul Rice	$19	$16	$20	$19	$20	$19	$19	$22
Dry Rice ($0.40 per bushel)	$77	$63	$80	$74	$78	$76	$77	$87
Interest on Operating Capital	$10	$8	$7	$7	$7	$6	$4	$9
Custom Fertilizer Application	$19	$19	$19	$19	$19	$19	$19	$19
Fertilizers	$35	$35	$35	$35	$35	$35	$35	$35
Diesel Fuel	$31	$30	$30	$30	$30	$30	$31	$31
Repair & Maintenance	$30	$28	$28	$28	$28	$28	$30	$30
Irrigation Labor	$2	$2	$2	$2	$2	$2	$2	$2
Hand Labor	$0.61	$0.61	$0.61	$0.61	$0.61	$0.61	$0.61	$0.61
Irrigation Supplies	$.025	$.025	$.025	$.025	$.025	$.025	$.025	$.025
Insecticides	$6	$6	$6	$6	$6	$6	$6	$6

Table 12.5. Assumed fungicide applications per cultivar. [This graph is in a slightly different form in IS1342]			
Cultivar	**Disease**		
	Sheath Blight* @$27.39 per application plus aerial application fee	**Blast** @$27.39 per application plus aerial application fee**	**Smut*** @$15.36 per application plus aerial application fee**
Clearfield XL8			
Clearfield 161	1 application		1 application
Cheniere		1 application	1 application
Cocodrie	1 application		1 application
Francis		1 application	
Priscilla			
Wells		1 application	
XP710			

Table 12.6. Assumed insecticide applications per cultivar. [This chart is slightly different from on in IS1342]	
Cultivar	**Target Pests**
	Rice Water Weevil*/Stink Bug **1 application @ $5.67 plus aerial application fee**
Clearfield XL8	1 application
Clearfield 161	1 application
Cheniere	1 application
Cocodrie	1 application
Francis	1 application
Priscilla	1 application
Wells	1 application
XP710	1 application

Table 12.7. Rough rice yields, milling percentages, and value per bushel.

Cultivar	Rough Rice Yield	Milling Yield %			Value per bushel
	Bushels per acre	% Total	% Whole	% Broken	(rough rice)
Clearfield XL8	193	70.3	52	18.3	$2.93
Clearfield 161	159	67.8	56.9	10.9	$2.99
Cheniere	199	70.9	59.6	11.3	$3.13
Cocodrie	185	68.1	56.5	11.6	$2.99
Francis	195	65.5	50.4	15.1	$2.78
Priscilla	189	67.5	51.6	15.9	$2.86
Wells	193	70	49.4	20.6	$2.86
XP710	219	68.9	52.1	16.8	$2.90

*** Costs and returns are based on 3- year averages except for Clearfield XL8, Cheniere, and XP710. Value per bushel is based on $10.66 for whole grain and $5.33 for broken grains or $6.66 for 55/70.**

Table 12.8. Per acre returns above costs – specified rice cultivars.

Cultivar	Total Returns	Returns Above Direct Costs	Returns Above Total Specified Costs
Clearfield XL8	$566	$110	$49
Clearfield 161	$476	$84	$26
Cheniere	$623	$243	$185
Cocodrie	$553	$180	$122
Francis	$542	$184	$126
Priscilla	$540	$217	$159
Wells	$553	$195	$135
XP710	$636	$224	$164

Mississippi and US Rice Statistics

Figure 12.1. Mississippi Rice Yield 1993-2006 (2006 estimated*).

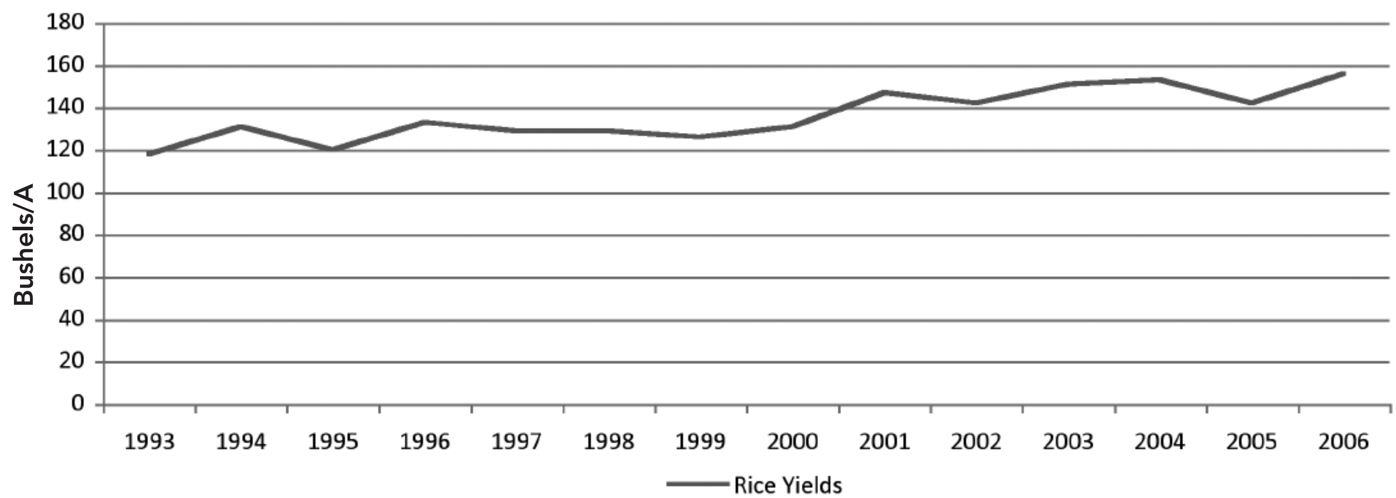


Figure 12.2. 2007 US Rice Planted Acres by State.

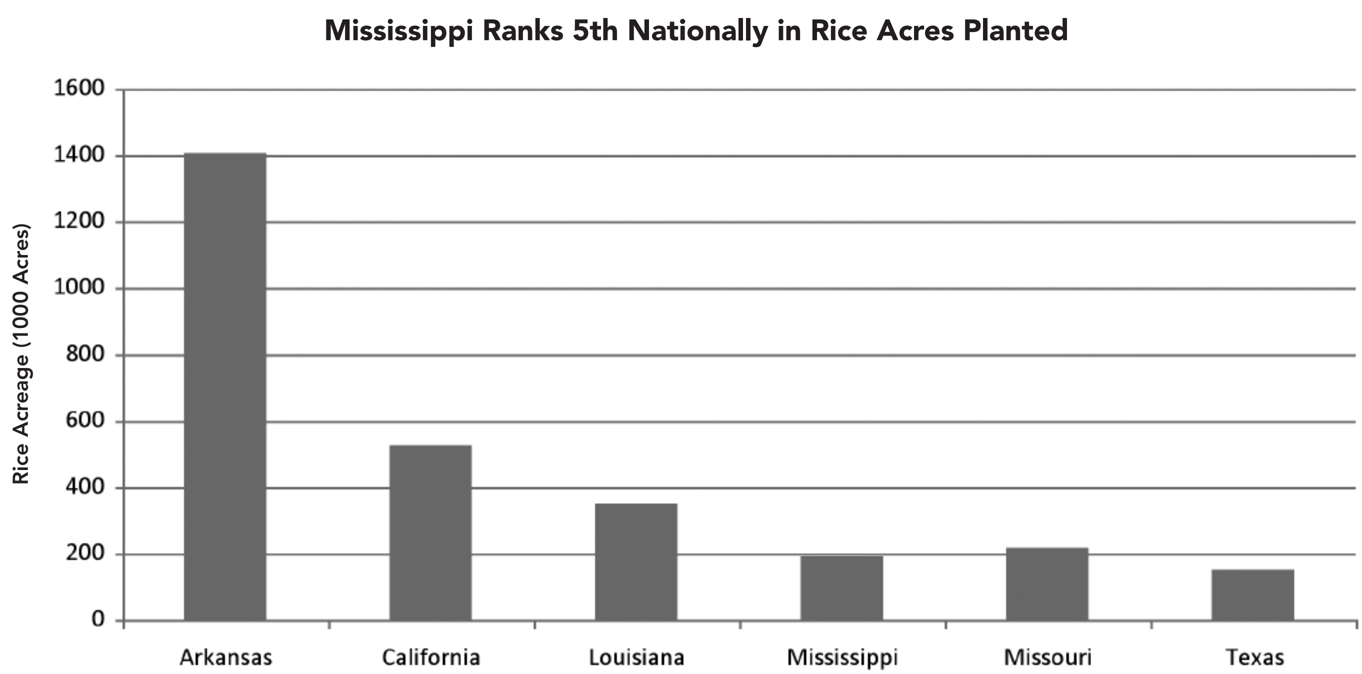


Figure 12.3. World Exports (Milled Basis) by Country in 2006.

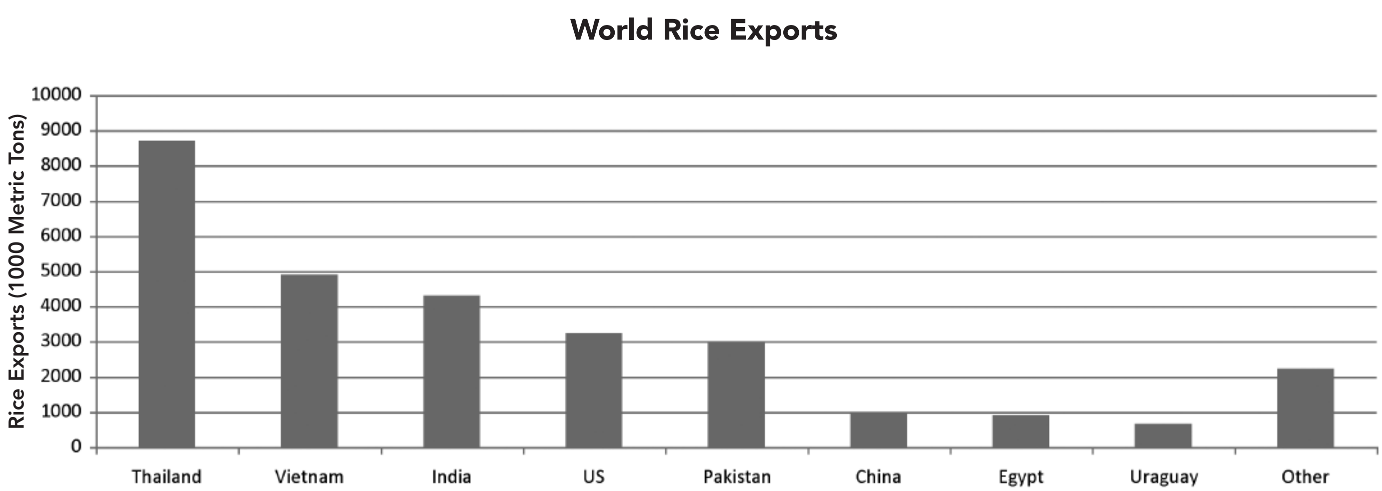
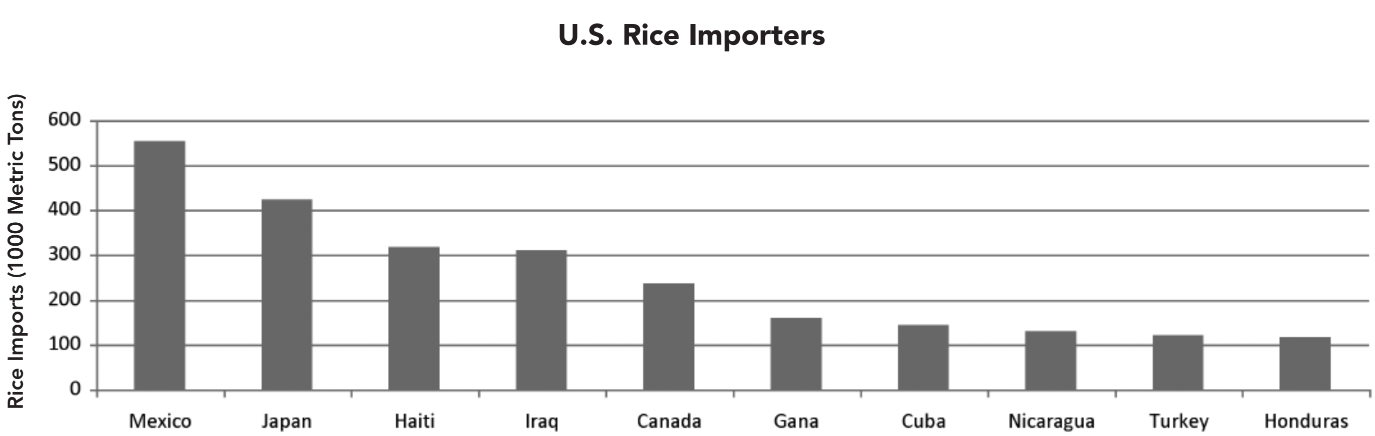


Figure 12.4. Top Ten US Rice Importers (Milled Basis) in 2004.



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