B-6131
1/2023

Texas Rice Production Guidelines

2023



Texas A&M AgriLife Research

2023 Texas Rice Production Guidelines

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These guidelines are based on rice research conducted by personnel located at the Texas A&M AgriLife Rice Research Center at Beaumont and the David R. Wintermann Rice Research Station at Eagle Lake, Texas A&M University in College Station, and with the Texas A&M AgriLife Extension Service in College Station. This publication, with distribution by County Extension Agents, was undertaken to provide rice farmers and landowners with the latest production and economic information for the Texas rice crop.

Funding for the 2023 Texas Rice Production Guidelines was provided by Texas A&M AgriLife Research at Beaumont and Eagle Lake.

Cover art developed by Megan Enard and Brandy Morace

The 2023 Texas Rice Production Guidelines can be downloaded from:
https://beaumont.tamu.edu/eLibrary/RiceProductionGuidelines.htm

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Updated 07/2022

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INTRODUCTION

L. T. Wilson, X. G. Zhou, S. O. PB. Samonte, B. Morace, and M. O. Way

Brief Historical Overview

Rice production in Texas began in the 1850s near Beaumont. In 1898, 3,000 acres of rice were irrigated in Jefferson County. By 1954, Texas produced rice on nearly 637,000 acres. Texas rice yields increased dramatically from less than 1,000 lb/ac in 1900 to over 4,000 lb/ac in 1970 to a current average of close to 8,000 lb/ac. Some Texas rice farmers now routinely produce over 13,000 lb/ac for the main plus ratoon crops. Rice production in Texas has averaged 181,000 acres over the past five years and remains one of the top five field crops in terms of dollar value.

General Purpose

The 2023 Texas Rice Production Guidelines is a compilation of current knowledge about the rice crop and its production and management. It also contains links to useful information pertinent to the Texas rice industry, including the Texas Rice Crop Survey, weather data, and research reports. The information serves as a guide and reference for Texas rice producers, crop consultants, County Extension Agents, Extension-IPM Agents, university researchers, and students involved in rice research. Electronic copies can be downloaded from http://beaumont.tamu.edu/.

Growing rice profitably and sustainably is a challenge, with plant varieties, management practices, pest pressures, climate stresses, and the economics of production constantly shifting. Many of these challenges have been and will be met in the future by research conducted at the Texas A&M AgriLife Research Center at Beaumont, the David R. Wintermann Rice Research Station at Eagle Lake, the College of Agriculture and Life Sciences in College Station, and in other states.

Much of the research designed to help the Texas rice industry is funded by the Texas Rice Research Foundation (TRRF) and the Texas Rice Producers Board (TRPB), both of which are managed by growers for growers. Other support for research and outreach activities includes funding provided by Texas A&M AgriLife Research, Texas A&M AgriLife Extension Service, federal and state competitive granting agencies, agricultural industries, and private entities. Without this support, the research and extension results that are presented in the Texas Rice Production Guidelines would not have been possible.

Several individuals contributed either directly or indirectly to the guidelines, including all the staff in Beaumont and College Station who work on rice, crop consultants, and extension agents. Each year, growers, consultants, extension agents, seedsmen, dryers, and millers from across the Texas rice belt selflessly and repeatedly provide crop survey data. Special thanks to our authors, which include Drs. Lena Bernaola, Fugen Dou, Omar Samonte, Rodante Tabien (retired), Shyamal Talukder, Lee Tarpley, Yubin Yang, Mo Way (retired), Ted Wilson, and Shane Zhou, and staff including Karin Leon, Brandy Morace, Jason Samford, Jenny Wang, and Zongbu Yan with Texas A&M AgriLife Research, Drs. Young-Ki Jo, Joe Outlaw, and Marc Raulston with Texas A&M AgriLife Extension Service, Drs. Muthu Bagavathiannan and Ted Wilson with Texas A&M

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RICE CROP

Growth and Development

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Seasonal Progression of Rice Growth and Development

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This chapter provides an overview of the seasonal progression of rice growth and development, highlighting major features of each crop stage. Through the course of a growing season, rice undergoes a progression of stages from seedling development to early tillering, late tillering, panicle initiation, flowering, and grain development, all as part of the main or first crop (Fig. 2a). When the length of the season or accumulation of heat units in a growing season is sufficiently long, as often occurs for early-planted rice fields in Texas and parts of Louisiana, rice can also produce a second crop, which is referred to as the ratoon crop.

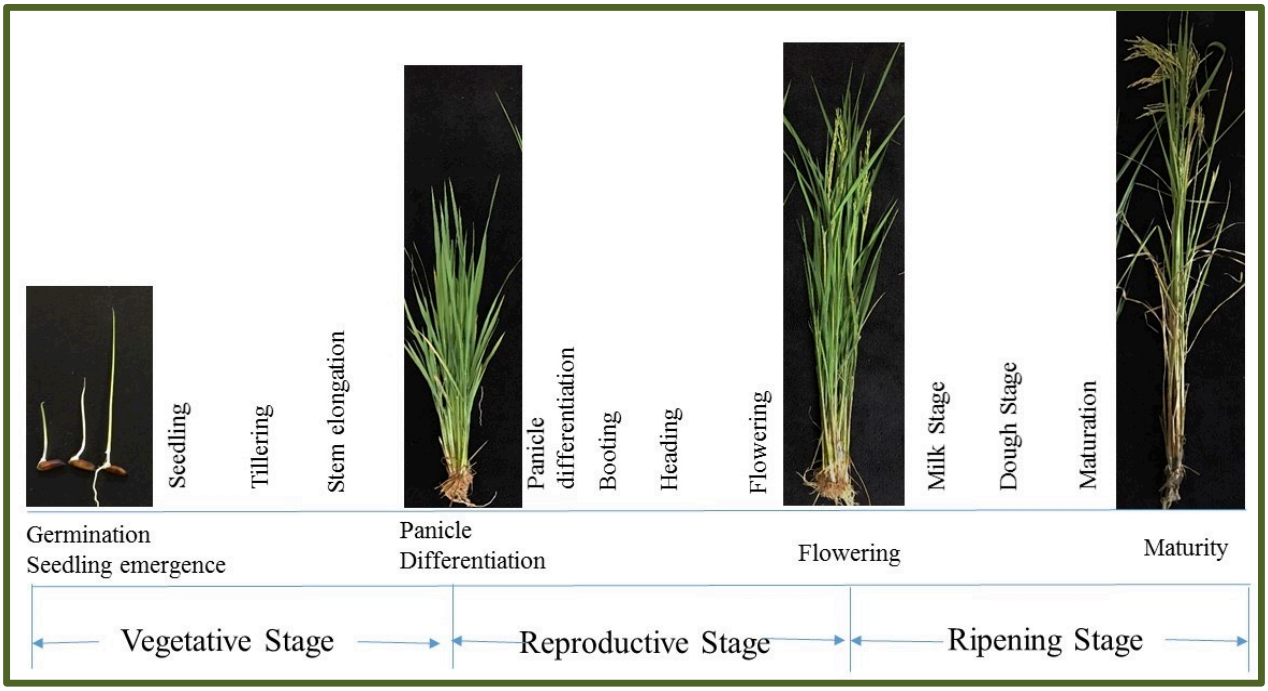


Fig. 2a. Successive stages of rice crop growth and development (photo by R. E. Tabien).

Seedling Development

From seed germination to seedling emergence the rice seedlings sustain themselves through nutrients provided by the seed. Prior to seedling emergence (Fig. 2b) a rice plant begins to rapidly develop a root system to draw water and nutrients from the soil and a leaf and stem system to produce carbohydrates, protein building blocks, plant hormones, and other compounds. The radicle is the first root at germination and the first to emerge under aerated conditions followed by the

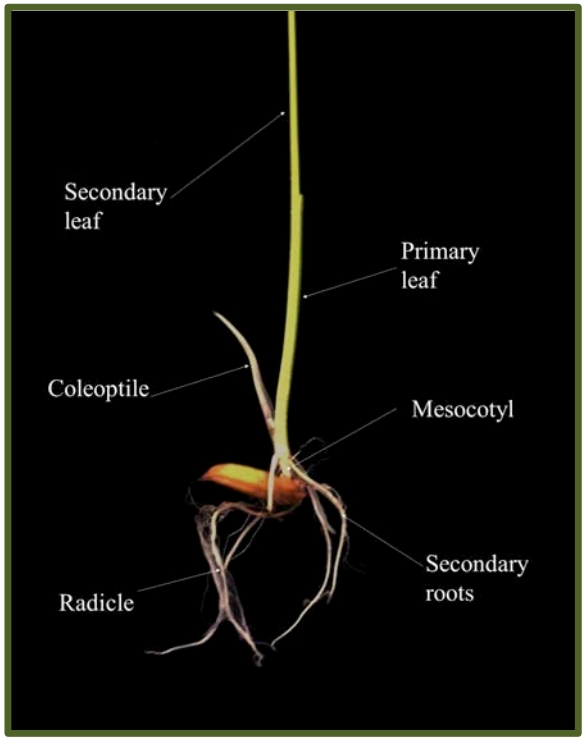


Fig. 2b. Parts of a rice seedling (photo by R. E. Tabien).

coleoptile. Aerated refers to the presence of oxygen in the soil, which is the normal condition for rice paddies that have not been flooded. The secondary roots follow to form the adventitious roots in later stages of rice growth. The shoot part at germination has a coleoptile, mesocotyl and leaves. The coleoptile, which is the first leaf produced on a rice plant, is the first to emerge under anaerobic conditions followed by the radicle. The coleoptile is not a true leaf but has leaf-like characteristics. Anaerobic refers to the absence of oxygen in the soil, which is the normal condition for rice paddies that have been flooded. The mesocotyl is a short stem that is usually prominent when germination occurs in the dark such as beneath the soil surface. The mesocotyl lifts the growing shoot (crown) up near the soil surface at emergence. The first true leaf of a rice plant is the primary leaf, which emerges after the coleoptile splits.

Once seedlings emerge above the soil surface, leaf mass begins to rapidly increase to sustain the young plants on the sun's energy and the soil's nutrients. Rapid production of new leaves and new leaf area allows the seedlings to suppress, through shading, the germination of weed seeds and development of weed seedlings. The stored food and minerals supply from the seeds is used by the developing seedling and are depleted at about the 3-leaf stage. If the root or leaf system develops too slowly, often due to unfavorably cool temperatures, injury from soil pathogens and insects, or competition for light and nutrients from weeds will result in decreased seedling vigor, stunting, and an increased likelihood of seedling death. Micronutrient deficiencies can appear at this stage as the young seedling first becomes dependent on the soil for its nutrients.

Soil temperature is a major factor that influences germination and seedling development. Although rice seeds begin respiring at around 50˚F, germination and seedling growth do not begin to increase rapidly until temperatures reach about 68°F. Prolonged temperatures below 68˚F greatly reduce survival and can stunt seedlings, while brief temperatures below 50°F will induce seedling cold shock. Normal growth and development occur from 68°F to 88°F. As temperatures rise beyond 88°F, seedling growth slows due to acute stress injury leading to a rapid increase in the rate of respiration that uses the seedling's stored carbohydrates. Visual injury can occur above 94°F.

Extremely early planted rice is particularly subject to cool temperature or late frost seedling injury, and chlorophyll development can be prevented when the soil temperature drops below 60°F. Cold stress can cause a pale green coloration or yellowing in severe cases, which can be mistaken for nitrogen deficiency. As temperatures warm, later developing leaf tissues form chlorophyll normally. If the field is a uniform pale green, then the cause is cold stress; if rice plants

that grow on the levees are darker than those that grow within the paddies and if the lighter coloration within the paddies is spotty, then it is caused by low nitrogen. Cold-stressed plants are very susceptible to herbicide injury, so it is best to let fields recover before applying herbicides. If the newest developing leaves have a normal green color, then the plants have recovered from cold stress, even though the older leaves will remain pale in color. The data shown in Table 2a summarizes tests conducted over several years at Beaumont with progressive planting dates representing cool, moderate, and warm conditions at planting and the estimated seedling survival. The lower survival for the earliest planting is due to cooler soil temperatures, while the drop in survival from the mid-April to the mid-May planting is largely due to the soil drying too rapidly in mid-May causing increased seedling death.

Table 2a. Seedling survival across progressively later planting dates.

Planting Date	Seedling Survival
Mid-March	64%
Mid-April	78%
Mid-May	72%

Seedling germination and emergence require approximately 95 degree-days (DD) > 50˚F following planting, assuming the soil moisture is sufficient for germination and emergence. The deeper the seeds are planted, the lower the soil temperature. Similarly, the drier the soil, the longer the time and greater the amount of heat units required for seedling emergence. A DD in the crop's growth is defined as a soil temperature that is 1 degree above the temperature threshold for rice development (50˚F) occurring for a 24-hour period. Basing plant development on heat unit or DD accumulation automatically adjusts for differences in the effects of temperatures on the timing of plant developmental stages from location to location, across time during a season, and from season to season. In practice, the daily accumulation of DDs can be calculated a couple of ways. The easiest method is highly accurate if the minimum daily temperature is greater than 50˚F (Eq. 1). A description of different methods for estimating DD accumulation are described in Wilson et al. (1983), while different methods for calculating DDs are presented in Zalom et al. (1983).

$$\text{Daily DD} = (\text{Daily } ^{\circ}F_{max} + \text{Daily } ^{\circ}F_{min})/2 - 50 \quad (1)$$

Tang et al. (2009) presented a simple equation for calculating the number of DD required for seedling emergence, assuming soil moisture is sufficient for germination. This equation is presented below converted to DDs in Fahrenheit units (Eq. 2). While early DD accumulation is estimated based on soil temperatures, later DD accumulation is normally calculated based on air temperature but can also be calculated based on paddy water temperature.

$$\text{DD to emergence} = 81 + 13.3 \times \text{seed depth (inches)} \quad (2)$$

During the first 100 DD of crop development, the large majority of biomass is allocated to roots and stems. Once the root and stem structures are established, a progressively increasing proportion of biomass is allocated to leaf production as the plants shift from growth dependent on carbohydrates stored in the seeds to carbohydrates that are the product of photosynthesis (Table 2b). By the time tillering commences at about 860 DD, about 50% of plant biomass is found in leaves, 20% in roots, and 30% in stems and leaf sheaths, also referred to as culms.

Table 2b. Estimated proportion of biomass found in leaves, roots, and stems from early seedling to early tillering development (Wilson unpubl. data).

˚D>50˚F from planting	Leaf	Roots	Stems + Leaf Sheath
72	0.000	0.333	0.667
286	0.176	0.353	0.471
502	0.529	0.255	0.216
716	0.547	0.214	0.239

Dry blowing winds that occur during seedling development can cause a concentration of soil salts to accumulate on the soil surface (top 0.04") in the fields and levees, especially in sandy loam soils. The seedlings are discolored at the soil line and older leaves show burning from the tips moving towards the base of each leaf. Damage is more severe at higher salt concentrations and will kill the seedlings. High saline irrigation waters contribute most to salt build-up, but excessive nitrogen applications may also aggravate the problem. Flushing will help wash away the salt if fields are drained quickly. Do not let ponded water evaporate from the field, as this will leave the concentration of salt behind. Rice plants become progressively more tolerant of salt stress later in development.

Early Tillering

Photosynthesis begins to rapidly increase following tiller initiation. Plants use solar energy to convert CO_2 and water into sugars, some of which are used to produce new root, stem, and leaf mass during earlier stages of crop development. Some of the biomass produced through photosynthesis are converted into starch for storage while some are used to fuel the plant cells through cellular respiration. Leaves take up CO_2 from the atmosphere, while roots extract water and nutrients from the soil. The rate of photosynthesis is a function of temperature, solar irradiance (amount of sunlight), CO_2 concentration in the atmosphere, and the amount of nitrogen comprising proteins in the leaf chloroplasts, which is the machinery that drives photosynthesis. Sunlight striking the pigments in the chloroplasts provides the energy to combine carbon dioxide and water to produce sugar ($6CO_2 + 6H_2O + \text{light} = C_6H_{12}O_6 + 6O_2$).

Depending on the rice variety, a new node which contains a new leaf, leaf sheath, and culm is produced every 126 to 144 DD before panicle differentiation and every 180 to 252 DD afterwards (Wu and Wilson 1998). Hybrid varieties tend to produce new nodes more rapidly than inbred varieties. Tillering is generally initiated at the 5-leaf stage, but some varieties may initiate tillering at lower nodal positions. The early tillering stage of crop growth and development is responsible for establishing the necessary structure for future panicle and grain development. Stress during early tillering can reduce tiller production, which can in turn reduce subsequent panicle and flower production and the number of flowers that survive to develop into grain. A typical rice tiller and its component parts are shown in Fig. 2c). A mother plant is the shoot that begins development in the germinating seed. The primary or first tiller arises from the mother plant while the secondary tiller normally originates from the primary tiller but can also originate from the mother plant. Rice tillers are produced in a synchronous manner. Although successive daughter tillers are attached to the tiller from which they originated, after they have become established, each grows independently through the support of its own leaves and root system.

A rice leaf is composed of a leaf blade, leaf sheath, collar, ligule, and auricle. The leaf sheath covers the stem and anchors the attached leaf blade at a node to the culm. At the location where the leaf blade attaches to the leaf sheath is a band of tissue referred to as the collar. The two tiny appendages at the collar are called the auricle with the feathery membrane called the ligule.

Rice fields typically receive from zero to 5 flushes of water after planting and prior to permanent flood, with this variation due to different amounts of rainfall, soil moisture levels following planting, and temperature. Flushing is necessary to promote uniform emergence by preventing soil water stress. Water stress can reduce tillering and allow increased competition from weeds.

There is a perception that flooding stops rice tillering. Flooding will stop or reduce the rate of rice tillering if the water is too deep, too cold, or too cloudy. If about 1/2 of the plant is above water, tillering is not greatly affected. Good nutrient management is essential during this stage to ensure rice reaches its tillering capacity.

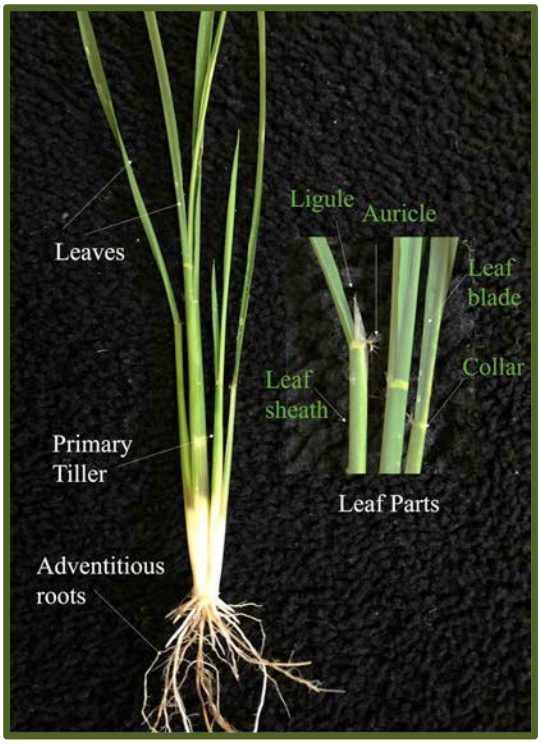


Fig. 2c. A mother plant, first tiller, and leaf parts (photo by R. E. Tabien).

Late Tillering, Main Crop Flowering and Grain Maturation

Rice tillers provide both structural support and energy for panicle production and growth. The last three leaves produced by a tiller provide much of the energy used to support the growth and development of flowers and grain. However, each tiller also stores energy in the form of starch in the culms and leaf sheaths, which is also used to support grain growth. Figure 2d illustrates a mother culm, which is commonly called a tiller, and three daughter tillers. During early tiller development, it is relatively easy to distinguish which tiller is the mother tiller and the order of production of daughter tillers. However, as tiller density increases, it is increasingly difficult to make this distinction.

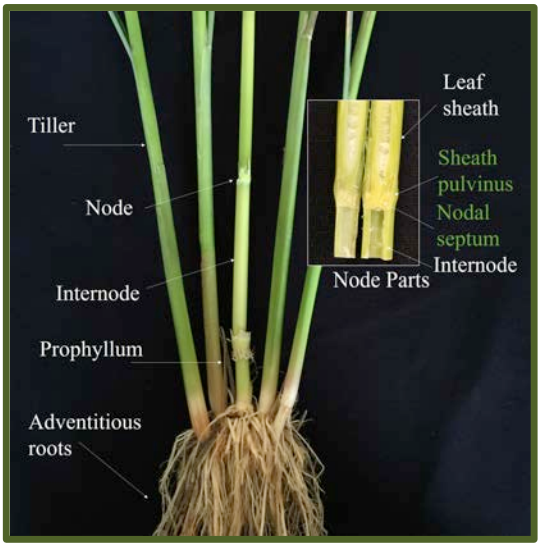


Fig. 2d. A mother plant with four daughter tillers, with different parts of a tiller shown. Lower leaf sheaths and leaves have been removed from the middle tiller to display a tiller node (photo by R. E. Tabien).

Each tiller has the potential to become reproductive and produce a panicle or grain head. Once a mother tiller produces a panicle, the large majority of daughter tillers that have produced nine or more leaves will also produce a panicle, but with an increasing time lag the later the daughter tiller is produced. With the exception of the first

two or three daughter tillers, the later produced panicles are increasingly smaller in size. As the demand for energy by grain developing on a panicle increases, starch is increasingly remobilized as sugar from the culms and leaf sheaths to developing grain. The culm of a rice plant is also called the stem and is composed of several nodes and internodes which collectively determine plant height measured from the ground to the panicle base. The internode of the culm is hollow while the solid part is referred to as a node. For each node, the solid portion that separates two internodes is called the nodal septum while the thick base part of the leaf sheath that anchors the leaf to the node is the sheath pulvinus. Each node has a leaf until the flag leaf. Nodal number is also called the leaf number. Lower nodes tend to produce nodal roots. Adventitious roots which are also called crown roots are composed of mat roots that are near the soil surface and ordinary roots beneath the soil surface. The prophylum is the leaf-like structure between tillers, such as between the mother plant and its primary (first) tiller.

Rice panicles or grain heads support the flower buds, flowers, and subsequently, the growing grain (see Fig. 2e-f). Panicles produce flowers beginning at the top of the panicle and progressively towards the base of the panicle. The length of the panicle is measured from the panicle base just below where panicle branches first originate to the panicle tip, which is the last node or uppermost

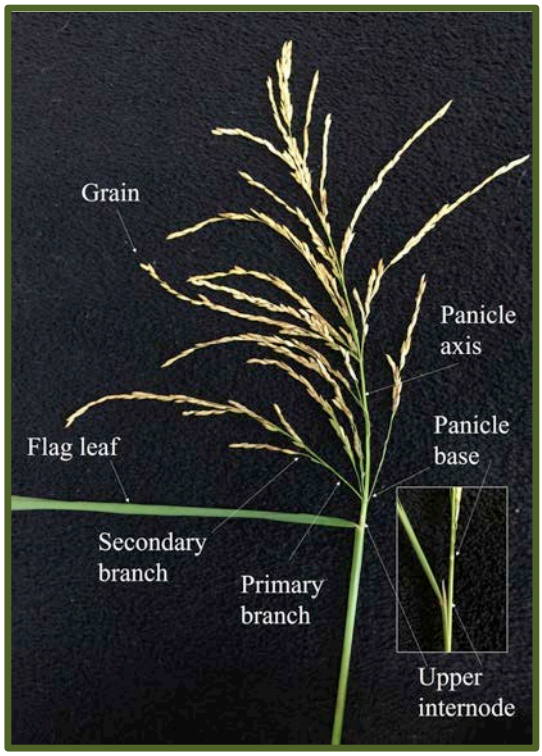


Fig. 2e. A panicle showing the primary and secondary branches, the panicle base and main axis, and to flag leaf, which is the last leaf produced at the top of a tiller just below the panicle (photo by R. E. Tabien).

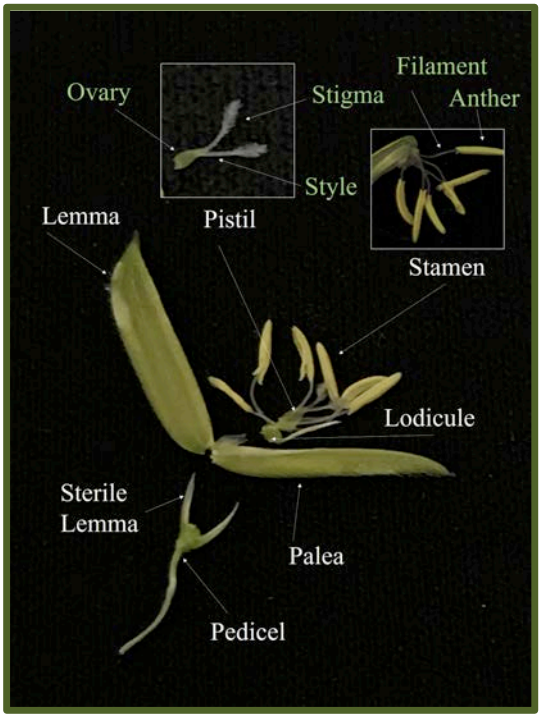


Fig. 2f. Female and male flower parts (photo by R. E. Tabien).

node. The top end of the middle stem of the panicle is referred to as the panicle axis. Secondary branches originate from primary branches that are attached to the panicle axis. The branches or vegetative structure that supports flowers and grain is referred to as the rachis.

Being a complete flower, each rice floret has both male (stamen) and female (pistil) parts. The stamen is composed of six anthers, each attached to a filament. The pistil has two feathery stigmas that accept pollen from the anthers. The pollen tube, which is produced by the germinating pollen, travels through the style and reaches the ovary where fertilization (combining of male and female gametes) occurs. The two glume structures that cover the floral organs are the lemma (the larger one) and palea (smaller/skinnier one), and these are the hulls at maturity. In some cases, the tip of the lemma, which is called the apiculus, has an awn. The lodicule anchors the ovary near the lemma and palea. The structure between the glumes and sterile lemma is called the rachilla. The whole floret is supported by a pedicle attached to the secondary and primary branches of the panicle. Pollination occurs in the morning. Hot or cold air temperatures and rainfall can prevent the pollen from fertilizing the flowers. Hot weather can cause pollen dessication and pollen inviability, as can low humidity. When either condition occurs, it prevents the flowers from being fertilized, causing sterility that reduces grain production on affected flowers. Typically, periods of high sterility are apparent by the presence of sections of panicles that lack grain or have large numbers of unfilled grain.

Grain development begins at flower fertilization, which progressively moves from older flowers and older grain near the tip of the panicle to younger flowers and younger grain at each panicle's base. Each rice flower has both female and male parts (Fig. 2f), and typically a large percentage of rice flowers are fertilized by male pollen produced by the same flower, thereby favoring self-fertilization. Exceptions occur with parental lines used for hybrid seed production, where one of the parents has functional female flower parts, but lacks functional male pollen. As a result, hybrid rice flowers are usually pollinated by pollen from surrounding "restorer" plants. In this case, restorers referred to rice plants that contain genes that over-ride the sterility that is normally caused by a gene found in the male-sterile plants.

The proportion of flowers that produce grain tends to decrease for flowers lower on a panicle and tends to be less for later produced panicles. A typical inbred variety will produce all of its flowers within a 2 to 3-week period, while a typical hybrid will do so in 3 to 4 weeks. The greater variability found with hybrids is partially due to the lower seeding rate of hybrids, which results in a prolonged tillering period and subsequently an extended period of panicle production.

The large majority of U.S. inbred and hybrid varieties produce panicles that extend above the leaf canopy. In contrast, a number of Asian "super rice" varieties produce panicles that are buried within the crop leaf canopy. Data produced by a sophisticated rice crop simulation model used by scientists with the International Rice Research Institute in the Philippines suggests that varieties that have the panicles inbedded within the leaf canopy have a greater yield potential than those with panicles that extendabove the leaf canopy. However, varieties with the panicles inbedded within the leaf canopy are more prone to fungal diseases unless they possess genes that confer resistance to these diseases. Additional research is needed to further unravel this issue.

During the earlier stages of crop growth and development, the rice plant has sufficient photosynthesis machinery to exceed the plant's ability to use the photosynthate for respiration and production of leaf, culm, and root mass. When this occurs, a rice plant reduces photosynthate production until production matches the rate of use. Collectively, this process is referred to as photosynthesis feedback inhibition. Photosynthesis feedback inhibition can begin shortly after the

initiation of tillering but is typically reduced or disappears entirely as plants increasingly require a greater amount of carbohydrates to support grain development.

Varieties that exhibit extended or repeated periods of photosynthesis feedback inhibition during a season typically produce fewer tillers and are lower yielding. This is illustrated in Fig. 2g for the main crop by the daily carbohydrate and nitrogen potential metabolic supply/demand balance occasionally increasing above a ratio of 1.0 for an early 1980s inbred plant type versus rarely, if ever, reaching a ratio of 1.0 for a modern high-yielding plant type, except late in the season after most of the main crop grain have matured and their demand for carbohydrate and nitrogen drastically drops. When the potential supply/demand ratio is above the dashed line, it signifies periods of crop growth when the capacity for photosynthesis and/or root nutrient uptake exceeds the plant's ability to use what it can produce or taking up. In contrast, periods when the supply/demand ratio is below the dashed line signify the plants are growing under stress and are producing photosynthates and/or taking up nitrogen at the maximum possible rate given the temperature conditions, level of protein in the leaf tissue, the level of CO_2 in the atmosphere, the amount of N available for plant uptake, and the growth potential of the plants' roots, culms, leaves, and grain. Older varieties tended to spend a greater amount of their development operating under feedback inhibition, which means the plants are not able to utilize their full photosynthesis potential. Modern varieties, particularly hybrids, operate under a far greater amount of metabolic stress due to a greater ability to use the products of photosynthesis and root uptake more efficiently. Varieties with these traits inevitably produce a higher grain yield if appropriate levels of plant nutrients and adequate pest control are provided to minimize biotic stress from mid-tillering through grain maturation.

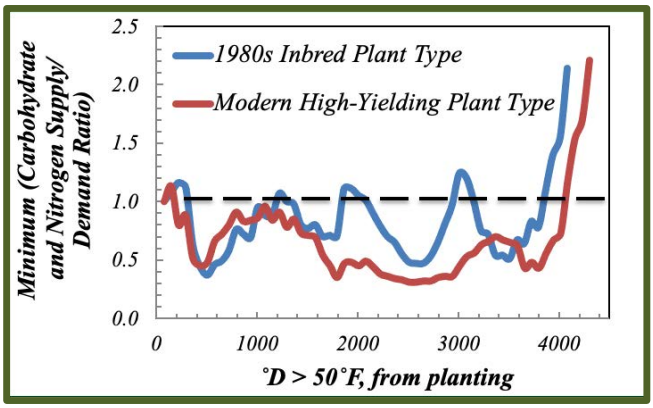


Fig 2g. Estimated seasonal pattern for the daily minimum potential carbohydrate and nitrogen supply/demand ratios (L. T. Wilson, unpubl. data).

High-yielding plant types tend to produce grain that are more variable in size due to the much higher level of carbohydrate stress that occurs during grain filling. Hybrids are particularly noted for increased variability in both grain length and width, but also in terms of the degree of chalkiness, also referred to as "chalk belly", which expresses itself by the presence of opaque areas of the grain which are caused by delamination of starch layers which is most prevalent during the period of rapid grain growth and high night-time temperatures. The whole grain and total milling yield of hybrid varieties have improved greatly since the first commercial hybrids were released in Texas in 2004. However, the increased chalkiness and greater variability in grain dimensions result in hybrids having, on average, a lower grade than inbreds.

Ratoon Crop Cycle

The ratoon or second crop is like the main crop, at least physiologically, except for two major differences. Firstly, while main crop tillers arise from tiller buds produced by the developing rice plants, the ratoon crop tillers arise from tiller buds that were produced prior to main crop harvest but had not yet expanded. These are located on the main crop culms below the height of the combine cutter bar. Secondly, the ratoon crop yield is inevitably much lower than that of the main crop, as illustrated by the right most part of Fig. 2g, which summarizes the main crop and ratoon crop yield variability across commercial rice fields over a 13-year period (2008-2020) adjusted to 2020 yields. If every rice producer in Texas were able to achieve 80% of the maximum observed main crop and ratoon crop yield, the average per acre yield would increase by 63% to 13,000 lbs of grain/ac, independent of any further increase due to newer higher-yielding rice varieties. This data identifies the dual importance of developing improved varieties and improved management practices.

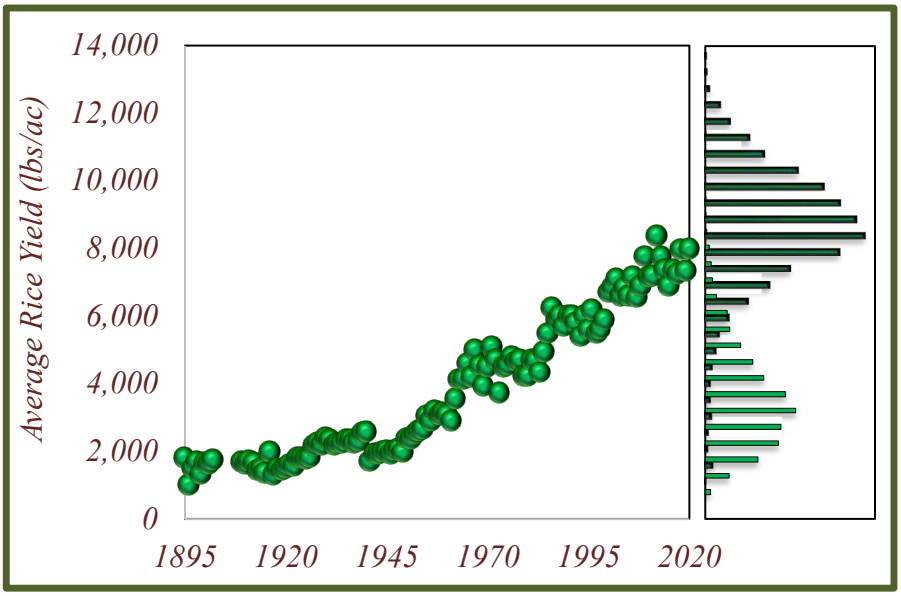


Fig. 2h. Historic Texas rice yields from 1895-2020 provided by NASS/FSA (left figure) and yield distribution from 2008-2020 Texas Rice Crop Survey data adjusted to 2020 yields (right figure) with main crop yield in dark green and ratoon crop yield in light green (from Wilson et al. 2021).

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Crop Survey

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The Texas Rice Crop Survey was developed to provide data on statewide and within-state regional rice acreage, crop growth and development progress, and grain yield and quality. The earliest version of the survey was developed in 1991 and maintained by Jack Vawter and Dr. Jim Stansel until 1999. In the early 2000s, Ted Wilson and Yubin Yang redesigned the survey into a web program. Several features have been added since then, including ratoon and organic crop production statistics, and many output options for tables and figures. The Texas Rice Crop Survey has two major components. The *Weekly Crop Survey* provides estimates of crop progression through planting, emergence, panicle differentiation, heading, and main and ratoon crop development (Fig. 3a). The *Yield Acreage & Variety Survey* provides detailed data on crop harvesting dates, yields, and grain quality by variety and by county (Fig. 3b). Each year, Brandy Morace and Karin Leon conduct weekly phone surveys with growers, consultants, extension agents, seedsmen, dryers, and millers from across the Texas

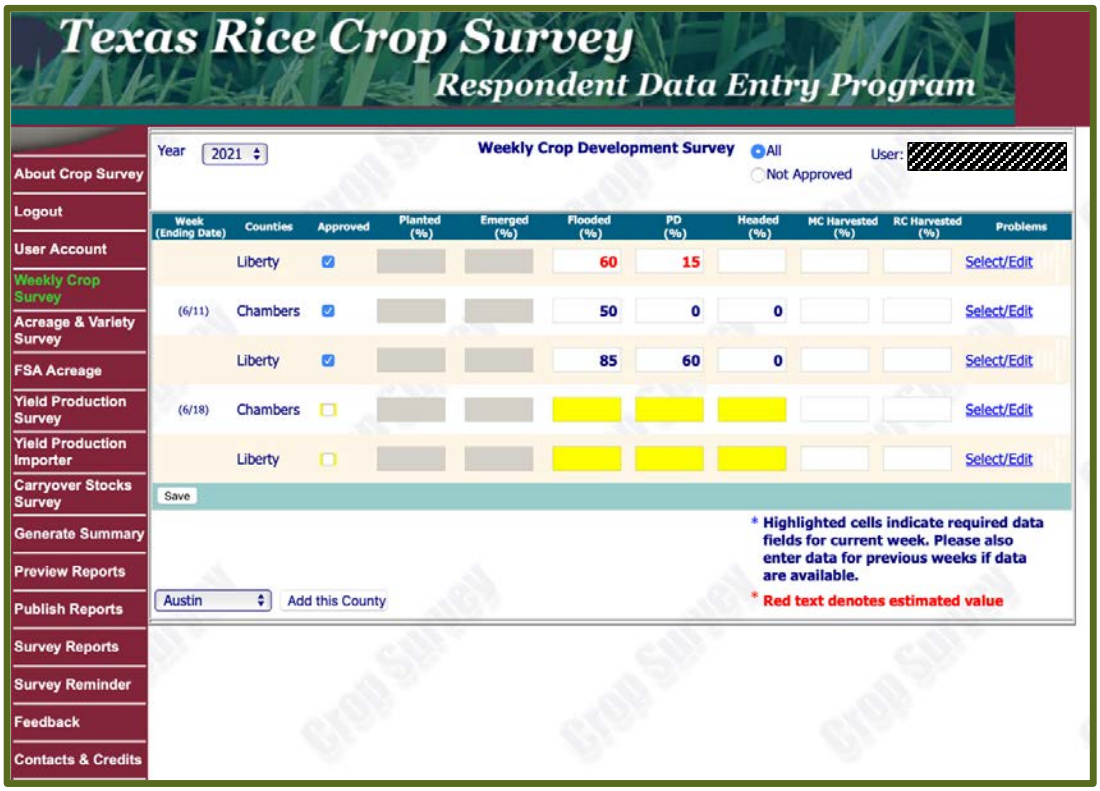


Fig. 3a. Texas Rice Crop Survey – Weekly Crop Survey.

rice belt. Special thanks to respondents through whose considerable effort and participation make the crop survey possible.

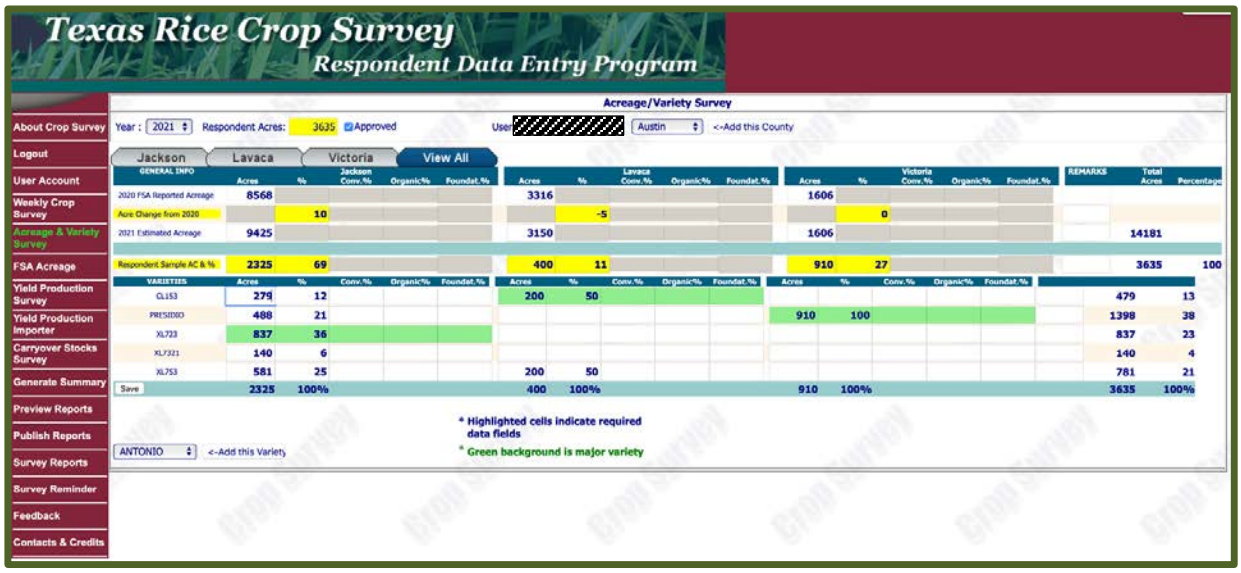


Fig. 3b. Texas Rice Crop Survey – Acreage and Variety Survey.

The Texas Rice Crop Survey has grown to be possibly the largest rice crop database of its kind in the U.S., and by the end of the current season, it will contain 32 years of crop development and yield data for ≈ 20,000 rice fields covering ≈ 2.0 million acres of rice production, or an average of about 64,500 main + ratoon crop acres per year. The survey indicated that from 1991 through 2003, at least 33 inbred rice varieties were commercially grown in Texas, while from 2004 to 2022, at least 41 inbred varieties and 33 hybrid varieties were commercially grown. The actual number of varieties grown in Texas during this period is probably at least slightly larger because there is a chance one or more varieties were not accounted for each year in the surveyed acreage.

One of the most important decisions a rice producer makes is whether to plant an inbred or a hybrid variety and whether to plant a conventional or herbicide-resistant type. Table 3a presents an analysis of the estimated average grain yield, whole grain and total milling yield, and net profit for these four types of rice, with the estimates obtained from the 2004-2020 survey data records, scaled to 2020 yields and 2020 production costs. The average main crop yield ranges from about 6,300 to 8,800 lbs/ac, with hybrids yielding on average about 1,600 lbs/ac more than inbreds, while average ratoon crop yield ranged from about 2,500 to 3,300 lbs/ac, with hybrids yielding on average about 700 lbs/ac more than inbreds. The milling yields of hybrids and inbreds are similar, with inbreds having about a 1% higher whole grain milling yield and hybrids about 1% higher total milling yield. However, these grain quality traits ignore the fact that inbred varieties have greater uniformity of grain dimensions and lower grain chalkiness, which are both desirable traits.

Table 3a. Estimated mean grain yield, whole grain and total milling yield, and net profit ($/ac) for conventional and herbicide-tolerant hybrid and inbred rice production derived from 2004 to 2021 crop survey data and scaled to 2021 yields and production costs, assuming $14.50/cwt.

	Conventional Hybrids	Herbicide Resistant Hybrids	Conventional Inbreds	Herbicide Resistant Inbreds
Grain Yield (lbs/ac at 12% moisture)				
Main Crop	8,197	8,286	7,343	7,311
Ratoon Crop	3,939	3,837	1,819	2,834
Main + Ratoon	12,136	12,123	9,162	10,145
Whole Grain Milling Yield (%)				
Main Crop	58.8	58.2	59.5	58.9
Ratoon Crop	54.8	53.9	54.8	54.6
Main + Ratoon	57.5	56.8	58.6	57.7
Total Milling Yield (%)				
Main Crop	71.8	71.3	70.7	69.8
Ratoon Crop	70.0	69.8	68.6	68.5
Main + Ratoon	71.2	70.8	70.3	69.5
Net Profit ($$/ac)				
Main Crop	-$180.44	-$213.92	-$28.68	-$141.66
Ratoon Crop	$377.84	$362.21	$115.55	$230.24
Main + Ratoon	$197.40	$148.29	$86.87	$88.58
Number of Fields				
Main Crop Fields	2,508	1,454	3,016	1,272
Ratoon Crop Fields	1,356	671	1,004	470

The estimated net profit for main crop rice production in Texas is negative for each of the four types of rice varieties, ranging from an average of -$28.68/ac for conventional inbred rice to -$213.92/ac for herbicide-resistant hybrid rice. These estimates were derived from a survey of yield and grain quality from nearly 12,000 conventionally produced Texas rice fields from 2004 to 2021, assuming a price of $14.50/cwt (including government support payments). When averaged across conventional and herbicide resistant varieties, main crop hybrid and inbred rice production nets -$197.18/ac and -$85.17/ac, respectively. In marked contrast, ratoon crop production on average provides positive returns that range from $115.55/ac for conventional inbreds to $377.84/ac for conventional hybrids. In total, hybrid and inbred main + ratoon crop rice production in Texas returns an average net profit of $172.90/ac and $87.83/ac, respectively, again assuming the price per hundred-weight indicated above.

These results are only part of the story and do not consider the variability in the distribution of net profits for each type of rice variety and the different degrees of economic risk associated with

this variability. The analyses presented above also do not consider specialty rice production, such as contracted organic rice, parboiled rice, parental-line, or inbred or hybrid foundation seed production, almost all of which yield considerably less than conventionally produced inbreds and hybrids, but demand much higher prices. Lower market prices, contracted production, and premiums for high grain quality all favor inbred rice production, while higher prices favor hybrid rice production.

Each producer also has land that differs in terms of soil type, rainfall pattern, fertility, insect, weed, and disease pressures, and yield potential. For example, rainfall "on average" is about 60% higher on rice- producing lands east of Houston than it is west of Houston. Similarly, the soils near Beaumont can exceed 64% clay, while the soils near Eagle Lake are often less than 30% clay. Heavy rainfall combined with heavy soils reduce the speed with which soils dry, which in turn delays planting east of Houston by an average of up to 3 weeks during wet springs compared to Eagle Lake. Our long-term survey data shows a yield reduction of ca. 310 lbs/ac for each week planting is delayed beyond the week of peak yield. Putting these numbers in perspective, growers near Beaumont who plant 1.5 to 3 weeks later than growers near Eagle Lake can expect a 465 to 930 lb/ac lower yield, everything else being equal.

In addition to differences in soils and weather, each producer also has a unique land/equipment lease/ownership business structure and debt load that impacts profitability by a small to a great degree from the numbers listed above. In summary, average profitability is a useful concept when looking at the health of an industry, but each grower must determine how their rice productivity and the cost of achieving their level of productivity translates into economic profitability.

Varietal Selection

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'Texas Patna' was the first variety released from the Beaumont Center in 1942. It reached heading at 136 days after planting and grew to 57 inches tall. 'Bluebonnet' was released 2 years later (1944) due to its earlier heading (105 days), shorter plant height (56 inches), grain yield of about 4,500 lb/ac, and 52% whole grain milled rice percentage. Over the next several decades, new varieties were released with improved straw strength (less lodging), semidwarf height, earlier maturity, disease resistance (hoja blanca, rice blast, and sheath blight), increased milling quality, and greatly increased main and ratoon crop grain yields. In addition to the conventional long-grain non-aromatic rice grown in Texas, new varietal grain types were also released, such as aromatic Basmati (e.g., Sierra and Dellmont) and Jasmine types (e.g., Jasmine 85), waxy rice (e.g., Neches), and rice for canning and parboiling (e.g., Sabine and Bolivar). Aromatic rice varieties, which have a popcorn nut-like aroma and taste when cooked, have historically not yielded as high as conventional rice varieties, but with equal production costs, they may be profitable due to higher market prices. Newer breeding methods offer tremendous potential for improving the yield of locally adapted U.S. bred aromatic varieties.

An important decision a rice producer should make before the start of each planting season is to select which variety to plant. The choice of variety depends on each production field's needs and the total production system being practiced. There are many rice varieties available for commercial production, and each has its own unique characteristics. All varieties, including new ones, have strengths and weaknesses. There is no single variety that fits all growers. A variety may perform well for one grower but not for another. Since new varieties may not fit all growing conditions, a recommendation is for a producer to grow them on a trial basis to observe their performance to decide whether to grow a new variety on larger acreage. Variety adoption is very dynamic. Some varieties, such as Lemont, Cypress, Cocodrie, Presidio, and XL723, were planted for many years and had extended longevity, but others were planted for just a few seasons due to various reasons, such as yield potential, grain quality, change in disease prevalence or market preference.

In the past five years (2017 to 2021), based on the Texas Rice Crop Survey (Wilson et al. 2022), 33 rice varieties have been grown in Texas by farmers or seed producers (Table 4a). These varieties are classified into two major types – inbreds and hybrids. Hybrid rice varieties accounted for 45-55% of the Texas rice acreage, for a 5-year average of 51%, while inbred varieties ranged from 35-49%, for an average of 43%. Other varieties were grown on limited acreage and accounted for the remaining 6%.

Table 4a. Rice production in Texas by variety from 2017 to 2021 (Source: Wilson et al. 2022; https://beaumont.tamu.edu/CropSurvey/CropSurveyReport.aspx).

Varietal Type	Weed Mgt*	Variety	Rice Acreage (%)				
			2017	2018	2019	2020	2021
Hybrid	CL	CLXL745	11.97	11.25	13.46	15.04	8.14
Hybrid	Conv	RT7311	0.30	0.21			
Hybrid	Conv	RT7312	0.04				
Hybrid	Conv	RTLG	1.37			1.46	0.10
Hybrid	Conv	XL723	30.41	21.97	23.70	17.09	20.39
Hybrid	Conv	XL7301				7.92	
Hybrid	Conv	XL7321				1.60	9.27
Hybrid	Conv	XL7401					0.15
Hybrid	Conv	XL7521				3.01	0.93
Hybrid	Conv	XL753	6.38	16.21	5.40	6.74	16.30
Hybrid	Conv	XL754			1.66		
Hybrid	Conv	XL760	0.27	0.81	0.49		
	Subtotal (%)		*50.74*	*50.44*	*44.71*	*52.86*	*55.27*
Inbred	CL	CL111	4.63	0.95			
Inbred	CL	CL151	3.85	4.52	2.02	2.48	2.36
Inbred	CL	CL153	8.36	8.46	8.41	18.13	7.68
Inbred	CL	CL263					0.01
Inbred	CL	CLL16					0.04

Inbred	CL	CLL17					5.26
Inbred	CL	CLM04				0.61	
Inbred	Conv	Basmati	0.65				
Inbred	Conv	Cheniere	2.11	2.88	6.70	3.41	0.81
Inbred	Conv	DG263L					1.73
Inbred	Conv	Diamond		0.13	0.14	0.21	
Inbred	Conv	Dixiebelle	0.23	0.51	7.46	0.45	0.51
Inbred	Conv	Gemini			0.43	0.76	
Inbred	Conv	Gemini 214				1.23	
Inbred	Conv	Jupiter	2.55	8.32	10.39	1.43	3.14
Inbred	Conv	Mermentau	0.38	0.23			
Inbred	Conv	Milagro					2.00
Inbred	Conv	Presidio	20.30	11.05	11.14	11.52	4.66
Inbred	Conv	Texmati	5.76	5.24		0.69	1.70
Inbred	Conv	Titan		0.42			
Inbred	PV	PVL02					4.88
	Subtotal (%)		*48.81*	*42.70*	*46.70*	*40.92*	*34.79*
	Others (%)		*0.45*	*6.86*	*8.59*	*6.22*	*9.94*
	Total Acreage (acres)		169,858	191,988	154,052	180,369	186,641
Abbreviations: Conv = Conventional, CL = Clearfield, PV = Provisia							

Information on the performance of rice varieties can be obtained from seed growers, university publications, extension agents, farmers' trials, and the mass media. The influx of information can be overwhelming, with so many choices from both public and private varietal releases. Thus, the question of how to choose the best variety to grow is always recurring but critical. This chapter presents some bases for choosing which variety to plant.

Important Traits in Variety Selection

Yield and Agronomic Traits - Maximum net income or return is the goal of rice production, and this is usually brought about by high grain yield and desirable agronomic traits. The selected variety should produce at least an equivalent yield, or even better than the one currently grown. Height is important relative to the capacity of the combine harvester as varieties that are too short or tall may reduce the harvesting efficiency. Varieties with early maturity are essential if a second or ratoon crop is desired. Varieties with early maturity also reduce production costs, especially irrigated water expenses. Planting varieties with different maturities may help spread out the planting and harvesting load. Table 4b shows the height, heading, lodging, head and total rice percentages, and main crop grain yield of U.S.-released varieties entered for evaluation in the 2018 and 2019 Uniform Rice Regional Nursery (URRN) at Beaumont, Texas.

Grain Quality Traits - The grain quality traits generally considered in varietal selection include the grain length, width, length/width ratio, total and whole grain (head rice) milling yield, appearance traits such as chalkiness, fissuring, whiteness, translucency, and physicochemical traits

relating to cooking and parboiling properties, such as amylose content, alkaline spreading value, gelatinization temperature, viscosity, and aroma.

Table 4b. Grain yield, agronomic traits, and milling qualities of varieties in the 2018 and 2019 URRN trials at Beaumont, Texas.

Variety	Weed Mgt*	Average across 2018 and 2019					
		Height (cm)	Days to 50% Heading	Lodging (%)	Head Rice (%)	Total Rice (%)	Main Crop Yield (lb/ac)
Antonio	Conv	88	80	0	55.8	67.7	7,270
ARoma17	Conv	96	83	0	60.0	67.9	6,710
Cheniere	Conv	88	83	0	60.4	72.1	6,497
Cocodrie	Conv	85	79	0	56.9	69.7	6,421
Diamond	Conv	95	81	0	49.6	67.9	7,325
Presidio	Conv	88	78	0	60.5	70.6	6,146
Rex	Conv	95	83	0	52.5	64.4	7,330
Roy J	Conv	95	83	0	52.1	67.8	7,804
Thad	Conv	89	83	0	46.1	65.7	6,570
Trinity ‡	Conv	94	79	0	59.0	68.0	8,057
Wells	Conv	93	81	0	53.4	69.2	6,712
CL111	CL	87	76	0	58.7	70.9	5,410
CL153	CL	90	81	0	59.9	70.1	7,214
CL163	CL	96	83	0	52.6	64.5	7,686
CLJ01	CL	89	76	0	57.0	66.0	6,334
CLL15	CL	84	79	0	52.4	66.7	4,640
PVL01	PV	93	83	0	38.9	65.7	6,729
PVL02	PV	98	80	0	58.2	67.9	5,537
Jupiter	Conv	93	86	0	60.3	65.9	8,303
MM17	Conv	86	80	0	59.0	65.0	6,809
Titan	Conv	92	81	0	60.1	66.8	7,674
CL272	CL	93	86	0	57.9	69.2	6,151
CLM04	CL	98	83	0	54.2	66.0	7,871

* Abbreviations: Conv = Conventional, CL = Clearfield, PV = Provisia
‡ Presents data from 2019 only. URRN 2018 results were not included because its seed germination was negatively impacted by Hurricane Harvey in 2017.

Rice grain types classified based on size dimensions are short, medium, and long grain. Short, medium, and long-grain rice have length/width ratios of less than 2, between 2 and 3, and greater than 3, respectively (Fig. 4a). Long grain rice is very popular in the world markets, especially in the U.S. and countries in Europe, South America, and some parts of south and east Asia. The

required grain size dimensions with minimal variation (or high uniformity) are desired in a rice variety or crop.



Fig. 4a. Selected low-chalk, translucent, whole milled short, medium, and long-grain rice.

High milling yield quality is important for both inbred and hybrid rice. Brown rice is the product of dehulling paddy rice (also called rough rice), total rice is the product of milling brown rice and is composed of whole and broken milled grain, and head rice is the product of removing the broken grain and selecting the whole grain. Milled rice grain is considered whole if its length is at least 75% of the mean length of an unbroken grain. Total rice and head rice percentages are based on their ratios over rough rice. Whole grain yield is the primary determinant of the profitability of the rice crop produced. The by-products after milling are the hull, bran, rice germ or embryo, and broken kernels. Generally, most rice varieties in the U.S. have about 70% total and 55 to 60% whole milled grain. Based on crop surveys conducted on rice farms in Texas, hybrids had whole milled rice percentages of 57.6 and 55.1% in 2017 and 2018, respectively, while inbred rice varieties had 57.6 and 57.7%, respectively (Wilson et al. 2022).

Chalky grain (CG) is also used to evaluate rice grain quality. A whole milled rice grain is considered chalky if at least 50% of the exposed portion in its cross-section has a chalky or cloudy appearance (definition of the Federal Grain Inspection Service). Head rice with low CG% are more translucent and are desired for its uniform appearance. The chalky appearance is due to differences in light reflected from numerous air spaces between loosely packed starch granules from the tightly packed starch granules in the translucent area. Rice grain chalkiness is genetically inherited but highly affected by the environment, i.e., high air temperature. Thus, varieties can be selected for their low-chalky grain quality. Chalkiness, like other grain traits, can affect the price of milled rice. For the U.S Grade 1, 2, and 3 milled long grain rice, percent chalky grain of 1%, 2%, and 4%, respectively, are required. In addition, chalky grains tend to break during the milling process, thus producing a lesser quantity of whole milled grain (lower head rice yield).

Cracks in grain, also known as fissures, when severe, are visible in the milled rice and negatively affect the head rice recovery since they cause breakage in the mills. Fissuring is a genetically inherited trait and is also the result of varying moisture cycles in the field and improper postharvest handling. Thus, lower-fissuring varieties can be selected. However, fissuring is greatly affected by the environment. The cracking occurs in the field, and it is related to changes in grain moisture of mature grain. For example, daily weather changes alternating between dry and sunny days and humid and rainy days cause grain cracking.

The color of milled rice is also important. Milled rice color varies from white to grayish or yellowish and can be dull or translucent. The yellow color can be due to aging or higher protein or lipid content. White and translucent types are preferred.

Milled rice is primarily composed of two types of starch – amylose (straight chain of glucose molecules) and amylopectin (branched chain of glucose). Amylose content, also known as apparent amylose content or amylose percent, is a very important grain characteristic that affects the cooking quality of rice. Rice is classified as waxy (0-2%), very low (2-12%), low (12 to 20%), intermediate (20 to 25%), and high (greater than 25%). Waxy rice, also called glutinous rice, sticky, or sweet rice, is opaque white in its uncooked form, and it is very soft and sticky when cooked. In contrast, as amylose content increases, the cooked rice becomes less sticky and firmer. Consumer preference for the cooked texture of rice (firmness and stickiness) differs around the globe. In the U.S., the typical long-grain rice containing 20-25% amylose (intermediate amylose content) is predominantly produced in all the southern rice-producing states, while short and medium grain rice with lower amylose concentration is predominantly produced in California. The medium grain of low amylose content rice is also the preferred type for producing rice cereal, while high amylose content rice is preferred for the canning industry and making rice noodles.

Alkali spreading value is a simple laboratory test that measures the degree of disintegration of milled rice kernel in an alkaline solution, and it is used to estimate the gelatinization temperature of the rice grain, which is the temperature at which rice grain start to absorb water during cooking. An alkali spreading value of 3 to 5 indicates an intermediate gelatinization temperature, which is common for the popular long-grain rice grown in Texas. Viscosity is measured by an instrument that is referred to as a rapid visco analyzer, which determines the thickening ability or paste viscosity of rice when cooked. Viscosity is measured as hot paste or cool paste. Hot paste viscosity is measured on a flour slurry after heating at 203°F, while cool paste viscosity is measured on a slurry cooled at 122°F after heating at 203°F. The rapid visco analyzer test is especially useful for selecting high amylose content rice that is suitable for canning and parboiling processes by the industry. A typical high amylose content rice that is preferred for canning and parboiling has a cool paste value above 350 rapid visco units. Table 4c shows the grain quality trait classifications of rice varieties entered in the URRN in 2018 and 2019 in terms of grain size, aroma, amylose, and gelatinization temperature.

Disease Resistance - Varieties differ significantly in their resistance or susceptibility to rice diseases. Therefore, selecting a variety with an acceptable resistance level is key to effective disease management. Rice diseases cause significant damage to Texas rice every year due to the long, warm, and humid cropping season that is favorable for the development of many diseases. Seedling diseases, sheath blight, rice blast, narrow brown leaf spot, and kernel smut are among the most important diseases in Texas. Bacterial panicle blight, brown spot, kernel smut, and straighthead (a physiological disorder) can also cause considerable loss of yield and quality of rice in epidemic years. Although none of the current varieties are highly resistant to all diseases, farmers should plant a resistant or partially resistant variety as often as possible. Varieties with a high level of resistance to rice blast and narrow brown leaf spot are available, but not to sheath blight and bacterial panicle blight. The resistance ratings of rice varieties to sheath blight, rice blast, narrow brown leaf spot, kernel smut, bacterial panicle blight, brown spot, and straighthead under Texas environments are available in the Disease Management chapter of this book. Please

consider the disease reaction in your selection of varieties to plant in the coming rice cropping season.

Managing disease resistance in released varieties is also important to prolong their use in production. Disease resistance breakdown, i.e., when a resistant variety is overcome by the disease pathogen and the variety becomes susceptible, is possible when a single resistant variety is used consecutively for several years. Variety rotation or replacement is recommended to minimize such

Table 4c. Grain quality of varieties from the 2018 and 2019 URRN trials at Beaumont, Texas.

Variety	Grain Quality Trait Classification			
	Grain Size	Aroma	Amylose	Gel Temp
Antonio	L	Non-Aromatic	Int	Int
Aroma 17	L	Aromatic	Low	Low
Cheniere	L	Non-Aromatic	L202	Int
CL111	L	Non-Aromatic	Int	Int
CL151	L	Non-Aromatic	Int	Int
CL153	L	Non-Aromatic	Int	Int
CL163	L	Non-Aromatic	Hi	Int
CL172	L	Non-Aromatic	Int	Int
CL272	M	Non-Aromatic	Low	Low
Cocodrie	L	Non-Aromatic	L202 type	Int
Della 2	L	Aromatic	Int	Int
Diamond	L	Non-Aromatic	Int	Int
Jupiter	M	Non-Aromatic	Low	Low
Lakast	L	Non-Aromatic	Int	Int
Presidio	L	Non-Aromatic	Int	Int
PVL01Sub	L	Non-Aromatic	Low	Low
Rex	L	Non-Aromatic	Int	Int
Rondo	L	Non-Aromatic	Hi	Low
Thad	L	Non-Aromatic	Hi	Int
Titan	M	Non-Aromatic	Low	Low
Trinity	L	Non-Aromatic	Int	Int
Wells	L	Non-Aromatic	Int	Int
Roy J	L	Non-Aromatic	Int	Int
CLJ01	L	Aromatic	Low	Low
CLL15	L	Non-Aromatic	Int	Int
CLM04	M	Non-Aromatic	Low	Low
MM17	M	Non-Aromatic	Low	Low
PVL01	L	Non-Aromatic	L202 type	Int
PVL02	L	Non-Aromatic	Int	Int

breakdown. Both disease reaction and the prevalence of the variety in your production area are important in varietal selection.

Insect Pest Resistance and Tolerance - Plant resistance against the prevailing insect pests is also important in deciding which rice variety to plant. This decision will affect the total production budget. For a susceptible variety, the chemical and labor costs must be included in estimating the total cost of production. Relative to tropical rice-producing countries, the U.S. has fewer insect pest species that can severely affect rice production.

It is not clear whether current inbred, hybrid, and herbicide-resistant varieties differ in susceptibility to rice water weevil, and all varieties are susceptible to stem borers. However, hybrids do not produce as many whiteheads (a characteristic result of stem borer attack) as other varieties. Varieties with shorter periods of maturation from heading to harvest are less susceptible to rice stink bug damage compared to varieties with longer periods. In general, long-grain varieties are less susceptible to rice stink bug damage than medium-grain varieties (Bernhardt et al. 2002). A detailed overview of how rice stink bug damages rice can be found in Bhavanam et al. (2021). A detailed description of rice arthropod management is included in the Entomology chapter.

Response to Fertilization - Considering the high cost of fertilizers, fertilizer response information, particularly on nitrogen (N), should be considered when choosing a variety. Inbred rice varieties require more N than hybrid varieties to achieve their yield potential. A detailed description of rice fertility management is included in the Nitrogen Management chapter.

Herbicide Resistance and Tolerance - Weed management is a major activity in rice production, with many herbicides commercially available. Rice varieties can be classified as to whether they are herbicide-tolerant or not. Herbicide-tolerant varieties include Clearfield rice, which is tolerant to imidazolinone herbicides, Provisia rice, which is tolerant to Provisia herbicides (quizalofop p-ethyl), and FullPage rice, which is tolerant to Preface (imazethapyr) and Postscript (imazamox). These traits are important in deciding which variety to plant and in reducing the cost of weed management. A detailed description of rice weed management is included in the Weed Management chapter.

Rice Varieties - The list below obtained from the Texas Rice Crop Survey (Wilson et al. 2022) contains most of the conventional inbred rice varieties recently grown commercially from 2017 to 2021 in Texas, and Trinity which is a new variety released in 2021. For more information, Table 4a shows the rice varieties grown in Texas from 2017 to 2021 (https://beaumont.tamu.edu/CropSurvey/CropSurveyReport.aspx), their varietal type (i.e., inbred or hybrid), weed management (i.e., conventional or herbicide-resistant), and rice acreage percentages. Tables 4b-c show the varieties that were grown in the 2018 and 2019 URRN trials in Beaumont, Texas, and show their performance in terms of plant height, days to heading, lodging, head and total rice percentages, grain yield, grain size, aroma, amylose, and gelatinization temperatures. Each of these varieties are listed alphabetically and is briefly described below. Additional information can be obtained from the rice variety developer's websites.

Cheniere was released by the LSU AgCenter in 2003. It was developed from a complex cross using Newbonnet, Katy, L201, Lemont, and L202. Compared to Presidio, Cheniere is similar in main crop yield and height, but matures about 3 days later and has a slightly lower head rice

percentage. It is more susceptible to blast but less susceptible to sheath blight. Like Presidio, it is moderately resistant to straighthead.

Diamond was released by the University of Arkansas in 2016. It was derived from a cross between Francis and Roy J. It has excellent yield with good milling quality. Compared to Presidio, it heads about 2 days later and is about 5 inches taller. Diamond has good straw strength. It is more susceptible to rice blast but less susceptible to sheath blight when compared to Presidio.

Dixiebelle is an early-maturing, long-grain variety developed by the USDA at the Beaumont Center from Newrex, Bellmont, and CB801. Although Dixiebelle can be used as a conventional long-grain variety, it also possesses special qualities (like Rexmont) that make it preferable for the canning and parboiling industry. The main crop yield of Dixiebelle averages about 10% lower than Presidio, whereas ratoon yield and milling quality are similar. Dixiebelle is very susceptible to blast and sheath blight.

Jupiter was released by the LSU AgCenter in 2004, with Bengal, Mercury, and Rico-1 as its parents. It has better main crop yield potential than Bengal, but its milling yields are comparable. Compared to Bengal, Jupiter is similar in height and maturity, more susceptible to blast, but with similar or better resistance to sheath blight and panicle blight disease.

Mermentau is an early-maturing, long-grain variety with good grain and milling yield and excellent grain quality. It was developed by LSU AgCenter by crossing AR1188, Cocodrie, 9502088, and LaGrue, and was released in 2012. Mermentau has the same height and maturity as Cheniere and Catahoula but is slightly higher in yield. These three varieties have comparable head rice percentages. Mermentau is moderately susceptible to blast and straighthead and susceptible to rice sheath blight and bacterial panicle blight.

MM17 is a high-yielding, semidwarf, medium-grain variety released by Southeast Missouri State University in 2019. MM17 has a low amylose concentration that makes it a “sticky rice.”

Presidio is a long-grain variety developed from a cross of Jefferson, Maybelle, and Rosemont by USDA at the Beaumont Center and released as a variety in 2005. Compared to Cheniere, Presidio has similar main crop yield and matures about 2 days earlier. Presidio is known for its good ratoon crop potential. Presidio has excellent milling quality, which is slightly higher than Cheniere. Presidio inherited some blast resistance and moderate susceptibility to sheath blight from Jefferson.

Titan was released by the University of Arkansas in 2016. It was derived from a cross of M206, Jupiter, and line STG99F5-07-118. It is a very short season, semidwarf variety with good yield potential. It has good resistance to rice blast and a disease package similar to Jupiter. It is moderately susceptible to sheath blight.

Trinity is a new high-yielding, high-quality, long-grain rice variety developed at the Beaumont Center by Texas A&M AgriLife Research. It has low chalkiness that is comparable to Presidio, higher main crop and ratoon yield potential, but has not been observed to lodge. Compared to Presidio, Trinity heads 4 days later and is 2 inches taller. Parents of Trinity include Saber, Cocodrie, and Presidio.

The following hybrid rice varieties are listed on RiceTec's website at https://www.ricetec.com/products-services/ (accessed 8/16/2022) that have been recently grown (2017 to 2021) in Texas.

XL723 was released in 2005. It is an early-maturing, long-grain variety with high yield, ratoon potential, and good milling yield. It is ideal for straighthead-prone soils.

XP753 is an early-maturing, high-yielding, long-grain variety (released in 2011) with high ratoon potential. It is similar in stature and agronomics to XP723 but with major improvements in yield and grain retention.

RT7301, which was introduced in 2020, is an early-maturing, high-yielding, long-grain variety

RT7401 is a new variety for 2021. It is a medium-maturing, high-yielding, long-grain variety with high grain quality.

Several FullPage (FP) and Max-Ace (MA) varieties are mentioned on the RiceTec website. These include RT7321 FP, RT7421 FP, RT7521 FP, RT7523FP, RTv7231 MA, and RT7331 MA. The following are some Clearfield varieties listed on Horizon Ag's website at http://www.horizonseed.com/horizon/content/varieties (accessed 8/16/2022) that have been recently grown (2018 to 2021) or released in Texas. Furthermore, three Provisia rice system varieties (PVL01, PVL02, and PVL03) are mentioned on their website as developed to address ALS-resistant weedy rice and grasses.

CL111 is a long-grain variety released by the LSU AgCenter in 2010 and developed for the Clearfield production system. It has very early maturity, with a high yield potential approaching CL151. It has better blast resistance than CL151. It is nearly as tall as CL151 but less resistant to lodging. Compared to Presidio, CL111 heads about 3 days earlier, has similar height, and has slightly less yield (5%) and lower head rice percentage (1.8%). Its earliness and very good second crop yield potential are ideal for ratoon cropping.

CL151 is a very early-maturing, long-grain Clearfield variety with excellent yield potential and good ratooning ability. It is reported to have very good seedling vigor and consistently high head rice yields. It is moderately susceptible to lodging and susceptible to blast, sheath blight, and straighthead.

CL153 is an early-maturing, long-grain Clearfield variety developed by the LSU AgCenter and released in 2016. It has excellent grain yield and good grain quality. It has very good resistance to blast disease; it is susceptible to sheath blight and moderately susceptible to bacterial panicle blight.

CLJ01 is a medium-grain, high-quality, aromatic Jasmine-type Clearfield variety released by the University of Arkansas. Compared to Jupiter, it has similar yield potential but improved blast resistance.

CLL16 is a new long-grain Clearfield variety with high yield potential, milling quality, blast resistance, and standability. It heads about 5 days later than CLL15.

CLL17 is a new early-maturing, long-grain Clearfield variety with high yield potential and milling quality. It has resistance to blast and Cercospora.

CLM04 is the first high-quality, medium-grain Clearfield variety released by the University of Arkansas. Compared to Jupiter, it has a similar yield potential but with improved blast resistance.

DG263L is a long-grain DynaGro variety with high yield potential, high grain quality (low chalk), and good milling yields. It has good lodging resistance and moderate resistance to bacterial panicle blight and kernel smut. https://dynagroseed.com/seed-finder/rice/dg263l (accessed 8/16/2022).

Other Factors to Consider - Seed availability and cost, seeding rate, varietal adaptability, and market acceptability are also important factors to consider in choosing a variety. Older and newly released varieties may not be available in large quantities for large-scale rice production. Related to the seeding rate and nature of the variety (i.e., inbred, hybrid, and herbicide-resistant varieties), the cost of seeds will vary. Generally, seeds of inbred varieties are less expensive relative to those of hybrid and herbicide-resistant varieties. The adaptability of the variety to the target production area is also important to ensure high production. Varieties with wide adaptability or adapted to the range of environmental conditions at the rice producers' farm are preferred. Market acceptability depends on the demands of the local/target markets or importers in the case of exported rice. Basically, this covers the wishes of the packer, shipper, wholesaler, retailer, and consumer. High market demand is needed to enhance sales, recover costs, and gain profit.

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Development Advisory

Y. Yang, L. T. Wilson, J. Wang, J. Samford, F. Dou, and L. Tarpley

The Rice Development Advisory (RiceDevA) is a web-based program that forecasts rice growth stages for multiple varieties and different planting dates for rice-producing counties in Texas. It can be accessed at *http://beaumont.tamu.edu/RiceDevA*. A new version of the RiceDevA was released in 2023.

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RiceDevA provides growth forecasts and management advisories for most rice counties in Texas (Fig. 5a). It allows users to run multiple-field profiles at the same time and display and print results. The program provides interfaces for users to add, view, and edit their own weather data and allows users to view and download county weather data. Users can choose weather stations from any rice-producing county for a specific year, or historical averages for a particular station.



Fig. 5a. The RiceDevA provides growth forecasts and advisories for historic and current rice varieties for rice-producing counties in Texas.

To accurately forecast rice crop development, RiceDevA needs input data that includes rice variety, planting date, and 10% and 90% seedling emergence dates. Additional information used by RiceDevA includes weather station temperature data and year, or historical averages for the station. RiceDevA does not predict rice yields or account for changes in crop development due to management practices.

Interface window

The top pane of the RiceDevA interface displays links to the website of the Texas A&M AgriLife Research Center at Beaumont (Home, Research, Teaching, Extension, Outreach, Services, Personnel, and eLibrary) (Fig. 5a). The left pane displays links to the major features of the Rice Development Advisory (About Rice Advisory, Login, New Account, Account Info, Variety Info, Field Forecasts, County Forecasts, and Weather Data). The main pane of the interface allows users to input, edit, and view data or display results.

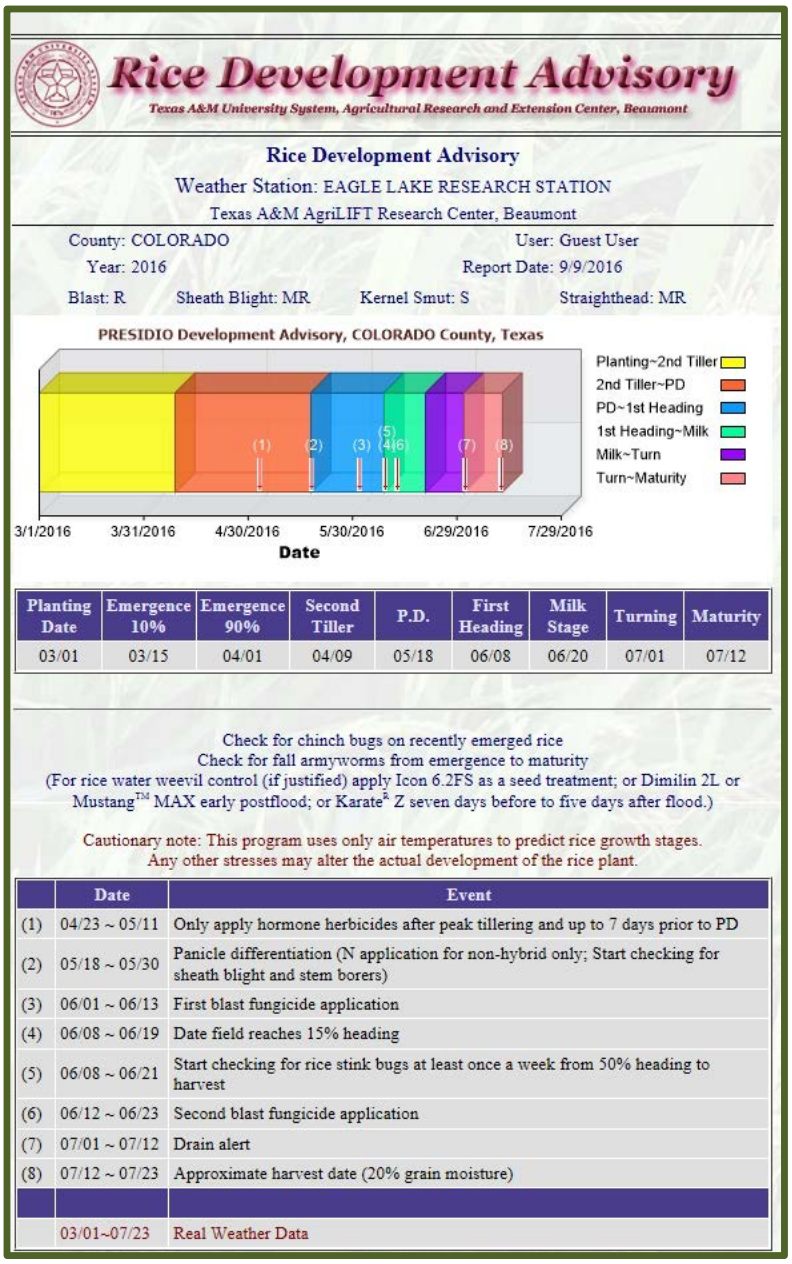
A user can access features in RiceDevA by clicking on a menu item in the left pane and making appropriate selections. **To create a new account**, click on the New Account link, fill in the appropriate information, and click on the Submit button. Once your account is created, you are automatically logged in and will be presented with more options in the left pane.

A **field profile** consists of the production and weather data needed to forecast rice plant growth stages. Production data include rice variety, planting date, 10% emergence date and 90% emergence date. Weather data include weather station and year or historical average for the station. A user can create a field profile by clicking on the Create Profile button under the Field Forecasts menu on the left pane and making the appropriate selections for production and weather data. Only users who have accounts with RiceDevA can save a profile or view, edit, or delete existing profiles. A field profile is owned by a specific user and is accessible only by that user.

Menus to access RiceDevA features are displayed on the left pane of the RiceDevA window (Fig. 5a). The *Account Info* menu displays information about a registered (username, user ID, email, etc.). The *New Account* menu allows a user to create a new account. A registered user (by creating a new account) has access to advanced features of RiceDevA. The *Variety Info* menu displays information about all varieties currently in the system, including 41 historic varieties and 11 current (2017-2021) rice varieties. For each variety, the information includes heat units required to develop to each crop stage (second tiller, panicle differentiation, first heading, milk stage, panicle turning, and grain maturity) and disease resistance (rice blast, sheath blight and straight head). The *Field Forecasts* menu provides growth forecasts for single or multiple field profiles for the current user. The *Create Profile* submenu allows users to create a new field profile; the *Edit/Run Profile* submenu allows a registered user to edit or run his/her existing field profile(s).

The *County Forecasts* menu allows users to forecast rice crop growth for different varieties, planting dates, and counties. The *Varieties* submenu provides growth forecasts for single or multiple rice varieties; the *Planting Dates* submenu provides growth forecasts for single or multiple planting dates; and the *Counties* submenu provides growth forecasts for single or multiple counties (Fig. 5b).

The *Weather Data* menu provides users background information about weather data and options for adding user weather data and viewing county weather data. The *Weather Data Info* submenu provides background information about weather data sources and usage; the *Add User Data* submenu allows a registered user to add user-specific weather data for new or existing user stations; the *View/Edit User Data* submenu allows a registered user to view or edit his/her weather data; and the *View County Data* submenu allows any users to view weather data for 21 rice-producing counties in Texas.



Rice Development Advisory

Texas A&M University System, Agricultural Research and Extension Center, Beaumont

Rice Development Advisory

Weather Station: EAGLE LAKE RESEARCH STATION

Texas A&M AgriLIFT Research Center, Beaumont

County: COLORADO | User: Guest User

Year: 2016 | Report Date: 9/9/2016

Blast: R | Sheath Blight: MR | Kernel Smut: S | Straighthead: MR

PRESIDIO Development Advisory, COLORADO County, Texas

Planting Date	Emergence 10%	Emergence 90%	Second Tiller	P.D.	First Heading	Milk Stage	Turning	Maturity
03/01	03/15	04/01	04/09	05/18	06/08	06/20	07/01	07/12

Check for chinch bugs on recently emerged rice
Check for fall armyworms from emergence to maturity
(For rice water weevil control (if justified) apply Icon 6.2FS as a seed treatment; or Dimilin 2L or Mustang™ MAX early postflood; or Karate® Z seven days before to five days after flood.)

Cautionary note: This program uses only air temperatures to predict rice growth stages.
Any other stresses may alter the actual development of the rice plant.

	Date	Event
(1)	04/23 ~ 05/11	Only apply hormone herbicides after peak tillering and up to 7 days prior to PD
(2)	05/18 ~ 05/30	Panicle differentiation (N application for non-hybrid only; Start checking for sheath blight and stem borers)
(3)	06/01 ~ 06/13	First blast fungicide application
(4)	06/08 ~ 06/19	Date field reaches 15% heading
(5)	06/08 ~ 06/21	Start checking for rice stink bugs at least once a week from 50% heading to harvest
(6)	06/12 ~ 06/23	Second blast fungicide application
(7)	07/01 ~ 07/12	Drain alert
(8)	07/12 ~ 07/23	Approximate harvest date (20% grain moisture)
	03/01~07/23	Real Weather Data

Fig. 5b. The RiceDevA forecasts the timing of major growth stages and provides stage-specific management.

AGRONOMIC MANAGEMENT

Land and Seedbed Preparation

F. Dou and Y. Yang

Importance of Early Land Preparation

Successful rice production requires timely land preparation. Therefore, fields should be plowed in the summer or early fall. Early land preparation is particularly critical when high residue crops such as grain sorghum or corn are planted the year before rice. If the land has been out of production and is covered with weeds and brush, prepare it as early as possible.

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Early land preparation allows repeated germinations of grass, weeds, and red rice to be killed by surface cultivation or chemically before planting. Cultivation also incorporates the crop residue to assure good decomposition of plant material to prevent early-season nitrogen deficiency.

If it is not possible to prepare the land early, plant material decomposition will not be at an advanced stage at the time of planting, and the soil's microorganisms (bacteria, fungi, etc.) that decompose crop residue will compete with rice seedlings for nutrients and can cause the developing rice to be nitrogen deficient. If this situation arises, you may need to add 10 to 20 more units of nitrogen per acre when the base fertilizer is applied at or near planting.

Seedbed Preparation

Seedbed preparation is particularly critical in coarse-textured soils. The seedbed should be firm and well pulverized to maintain proper moisture conditions for drilling and adequate soil seed contact. This will ensure rapid germination and emergence of the rice seedlings.

Although seedbed preparation is less critical in areas where rice is not drilled, it is still important to ensure that the desired soil condition is achieved to allow rapid emergence of the rice seedlings. In all situations, it is important to have a weed-free seedbed.

To reduce costs, minimize the number of times a field is cultivated before planting. Avoid "recreational" passes over the field. Research has shown that fields cultivated five times have about the same average yields as those more intensely cultivated. One custom cultivation with large tractors can cost about $12 per acre. Therefore, farmers who cultivate a field five times are adding as much as $60 per acre to the cost of land preparation and may not be realizing a corresponding yield increase.

Reduced Tillage

Reduced tillage refers to any effort to reduce the number of land preparation trips across a field. The discussion here will be restricted to spring and fall stale seedbed techniques.

Spring stale seedbeds provide less reduction in cultivation than do the fall stale seedbeds. The spring system involves normal fall land preparation with early spring seedbed preparation. The seedbed is allowed to settle and weeds to germinate. The weeds are controlled chemically right up to planting. The last burn-down application can be tank-mixed with a preplant herbicide application just before planting. With the spring system, the rice may be drill- or water-seeded. For uniform stand establishment, you must use minimum till or no-till drill.

The fall stale seedbed technique entails cultivation and seedbed preparation in late summer or early fall. Vegetation is chemically controlled through the fall, winter, and spring up to planting. The last burn-down application can be tank-mixed with a preplant herbicide application just before planting.

The major advantage of fall stale seedbeds is that they ensure optimum early planting, particularly in wet years when conventional spring field preparation is delayed because of wet field conditions. The fall system also is an excellent tool for the management of red rice. For more details on the spring stale seedbed technique, see the Weed Management chapter. Equipment and labor costs may be reduced because fields are not cultivated as often with reduced tillage; however, using burn-down herbicides can increase the total herbicide cost.

In a conventional cultivation system, the condition of the seedbed is often unknown until planting. This may make it difficult to select a seeding rate for planting. With the fall stale seedbed technique, when vegetation is managed properly, the seedbed condition is known for weeks or months before planting. Seeding rate selection and seed purchases can be completed well before planting.

In a fall stale seedbed system, the seeding rate can generally be reduced by 10 to 20% when drilling to moisture. Use a higher seeding rate if a germination flush will be required. This is critical if a preplant herbicide is used. Planting methods are limited to drill or water-seeding because broadcast seeding requires a seed incorporating tillage. Because the use of a minimum or no-till drill is essential, it may be necessary to invest in additional equipment. There is also the potential for extra herbicide usage.

Water-seeding is rarely used in Texas and is generally restricted to fields whose planting has been greatly delayed by prolonged adverse weather. Weed residue can cause oxygen deficiency, increase seedling diseases, and expose the seed to birds, particularly in water-seeded fields.

Reduced tillage can affect fertilizer management before establishing the flood, particularly if the soil surface has significant vegetative residue that restricts contact between the soil and fertilizer. To reduce potential nitrogen loss, apply the nitrogen to a dry soil and flush it into the soil as soon as possible.

Nitrogen applied to a wet soil cannot be effectively washed into the soil and is subject to more loss. Preplant nitrogen can be placed into the soil with a no-till drill or knifed in below the soil surface.

Several herbicides are labeled as preplant burn-down herbicides in a reduced tillage situation. The rates of application depend on the weed species and their sizes. Follow the label directions for rate, method of application, control of specific weeds and other restrictions.

Fall stale seedbed management generally increases the likelihood of planting to moisture even in heavy soils, which results in less stress from germination or early seedling flushes and increases yields. Early flushes can delay emergence and stress young seedlings. Seeding during the optimum planting window is also more likely, which further raises the main and ratoon crop yield potential. After flood establishment, cultural practices for reduced tillage are the same as for conventional tillage rice production.

Seed Treatments

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Seed treatments are increasingly used by Texas rice producers to protect rice from diseases and insects and to promote germination and emergence. The use of seed treatments can often provide a denser and more uniform stand. Rice seed can often be (and sometimes can only be) purchased pre-treated. Whether supplied as a pre-treatment or provided as a custom treatment, the seed treatment commonly contains an insecticide, fungicide, and/or plant growth regulator. Less frequently, other compounds are added. Currently, four insecticide-containing seed treatments are labeled for rice in Texas. Each has a unique spectrum of insect activity and effective rate based on the amount of active ingredient applied per 100 lb of seed and sometimes seeding rate. Since seed treatments are preventive, farmers must decide to purchase treated seed in advance of the occurrence and abundance of pest populations. Information on field history and location, target pest, varietal selection, seeding rate, planting date, method and timing of irrigation, and cost of the seed treatment can help the farmer make decisions. In general, recommended seeding rates are decreasing, especially with the hybrids; thus, seed treatments offer protection or "insurance" against possible unacceptable stand losses and future insect outbreaks, which can reduce yield and quality significantly. In addition, seed treatments minimize insecticide drift and reduce insecticide application costs and associated fuel usage. For more information on insecticidal seed treatments, see the Insect Management chapter.

The use of fungicide seed treatments is one of the most effective means to enhance stand, improve plant health and increase yield. Due to the high costs of hybrid rice seed, it is usually pre-treated. Recent disease surveys indicate that irregular and thin stands in the Texas Rice Belt are frequently associated with seed rot and seedling diseases caused by numerous soil-borne fungi and bacteria. Stand problems tend to be more severe in early planted fields where soil temperatures are low. Field plot experiments conducted at Beaumont and Eagle Lake demonstrate that fungicide seed treatments can increase stand by more than 20%. Several fungicides are available for seed treatment. For more information on fungicidal seed treatments, see the Disease Management chapter.

Plant growth regulators applied as seed treatments are primarily used to enhance germination and early seedling vigor, which commonly results in increased emergence, decreased exposure to soil diseases, a better stand and earlier crop canopy coverage. The most common plant growth regulator for rice seed treatment is Gibberellic Acid (GA), which appears in many commercial seed treatment packages. For drill-seeded rice, GA promotes seedling emergence by enhancing

elongation of the mesocotyl. Studies in Louisiana have shown GA seed treatment increases stand density by 50% and plant height by 38% at 20 days after planting, potentially permitting an earlier flood. Zinc is also commonly applied as a seed treatment to enhance early seedling vigor. Recently, seed treatments with beneficial endophytes (BioEnsure Rice) or a patented blend of endophytes (Indigo Rice) have been available commercially. These microorganisms live in rice plants and can promote rice plant growth, enhance tolerance to abiotic stress, reduce infection by plant pathogens, and potentially improve yield.

Seed treatments provide cost effective protection of the producer's investment and should be considered for use, especially when working with expensive seed or planting under sub-optimal conditions.

Water Conservation and Management

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Precision Leveling

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Precision leveling is the process of configuring the field shape and surface slope to optimize water management, crop production, and operation efficiency, and to facilitate a more even and shallower water depth within rice paddies (Fig. 8a). Precision leveling reduces the amount of water required for flushing and flooding, and greatly facilitates subsequent management for stand establishment, weed control, and field drainage for harvest. The flatter a rice paddy, the greater the crop vigor and uniformity of growth, and the greater the yield. Since precision leveling usually involves a reduction in the slope between adjacent levees and the levee density within a field, the levee area is reduced while the production area is increased. Since levees use less water than rice paddies, the water savings are partially offset by the increased water demand due to the increase in paddy area.



Fig. 8a. John Deere iGrade (http://blog.machinefinder.com).

Elevation change refers to the difference in elevation between the low and high end of a rice paddy. The greater the elevation change within a rice paddy, the more water is needed to cover the rice paddy. A rice field can be classified into bench, constant slope, and contour grade categories based on the levee density and field shape. Fields with a bench grade have straight and wide-spaced levees, and an average elevation change of 0.6 inches. Fields with a constant slope are graded to a lesser extent and have a moderate levee spacing and an elevation change of 1.8 inches. Fields with a contour grade follow the contour of the land and typically have a close levee spacing and a greater elevation change (3.0 inches) (Fig. 8b).

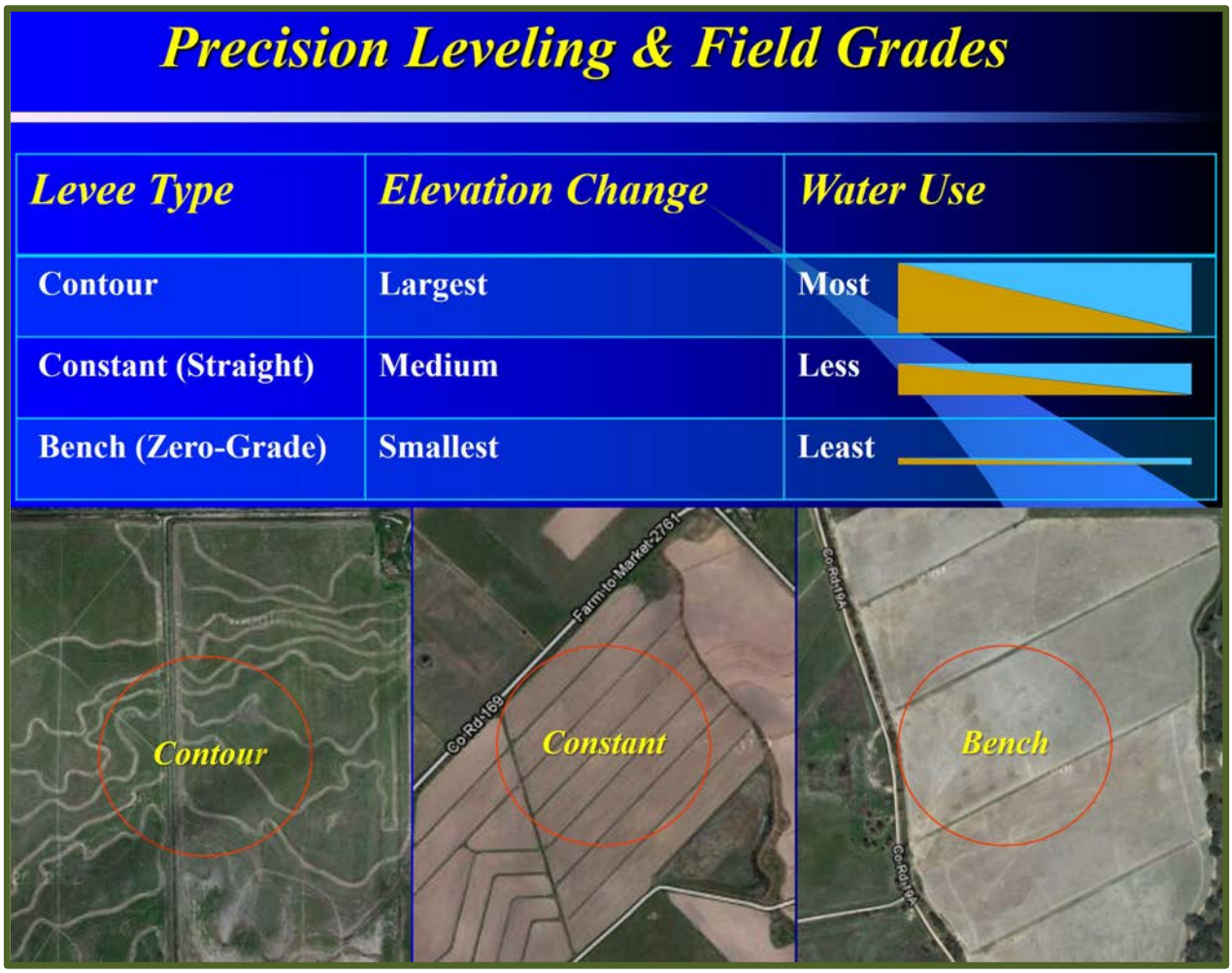


Fig. 8b. Field Grades and Elevation Change.

Multiple Inlet System

Traditionally, flooded rice is irrigated by releasing water into the portion of the field with the highest elevation, with water spilling into lower paddies through gate structures in a cascading fashion as the upper paddies fill (Fig. 8c). Although this is the simplest method to irrigate a rice field, it is not the most efficient. Instead of each paddy receiving overflow from a higher paddy, multiple inlet irrigation provides water to each paddy simultaneously via gates connected to a pipe or field lateral (Fig. 8c). The potential benefits of multiple inlet irrigation include reduced water loss, quicker flood establishment, improved fertilizer and herbicide efficiency, reduced irrigation pumping time and costs, reduced labor, reduced runoff, and shallower flood depth. Potential water savings from multiple inlet systems result from farmers being able to better time cutoff for irrigation water inflows to minimize tailwater loss, thus improving irrigation efficiency.

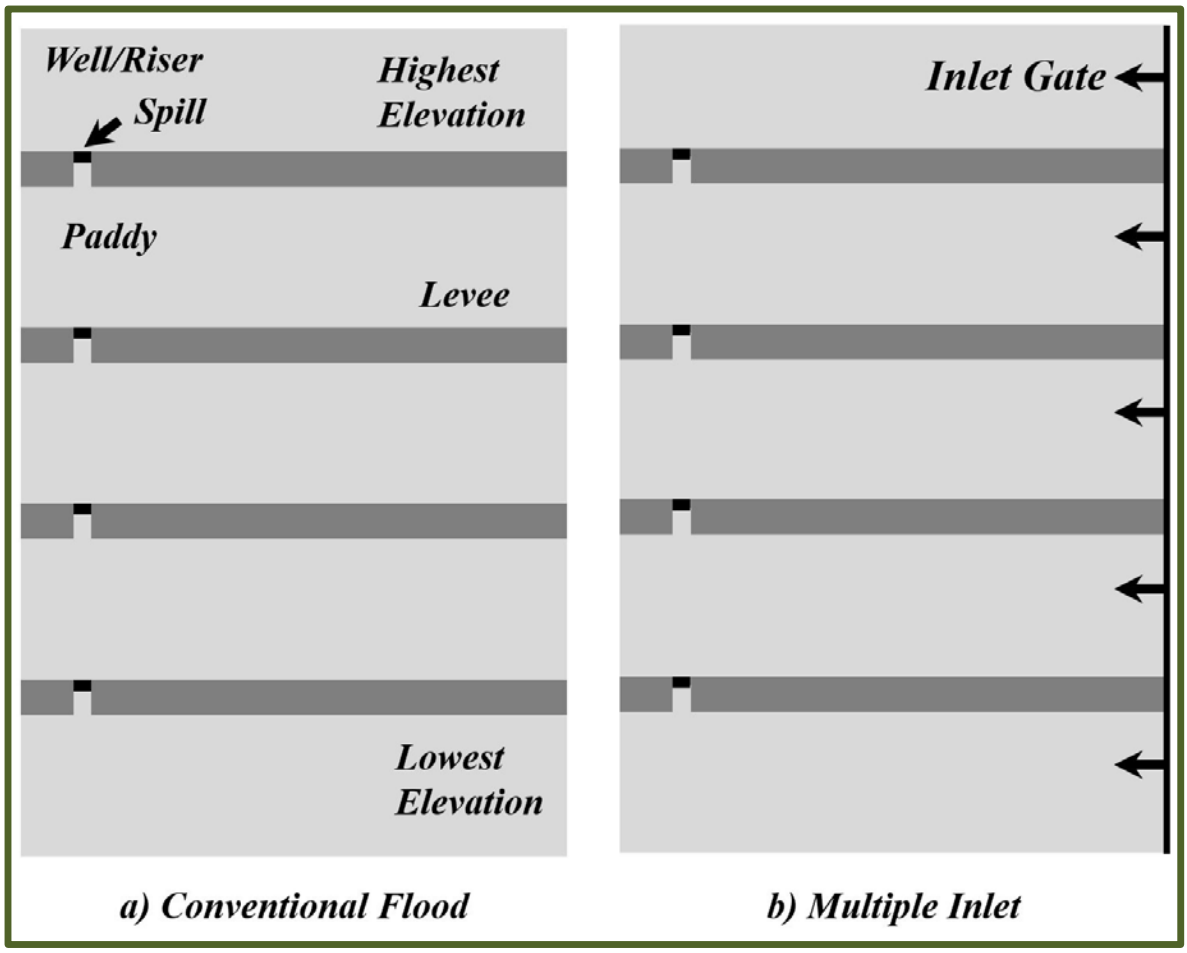


Fig. 8c. Multiple Inlets.

Conservation Tillage

Conservation tillage refers to any tillage and planting system that leaves 30 percent or more of the soil surface with crop residue after planting. Conservation tillage increases soil water storage, reduces evaporation and soil erosion, protects the quality of surface and ground water, and provides habitat for a variety of wildlife species. The potential benefits of conservation tillage include reduced labor, time and fuel use, machinery wear, and runoff. Conservation tillage in rice often reduces the number of flushes early in the season by retaining a greater amount of moisture in the soil prior to sowing. Furthermore, water loss through surface evaporation after sowing but prior to permanent flooding is reduced due to the cover provided by plant residues. As a result, one or two flushes may be saved depending on field and weather conditions immediately before and after sowing.

Lateral Improvement

Laterals are irrigation ditches that connect field(s) to the turnout of an irrigation canal. Lateral improvement involves the control of vegetation inside lateral ditches and on the lateral banks. Vegetation control reduces water use that is normally lost through transpiration. Aquatic weeds that grow on the water surface not only account for a large amount of water use, but also impede water flow, requiring a greater flow rate to deliver sufficient water to fields in a timely manner.

Effective weed control can eliminate much of this water loss. Lateral improvement can also involve the installation of underground pipes in place of lateral ditches. Burying rigid lateral pipes can almost eliminate lateral water loss, thereby conserving water and improving the efficiency with which water can be delivered to rice fields.

Tailwater Recovery System

Tailwater recovery systems facilitate the reuse of water by capturing tailwater from irrigation and rainfall. There are two approaches to tailwater recovery: reservoir-based and gravity-based. Reservoir-based tailwater recovery involves building on-farm reservoirs and retention ponds to recover tailwater from rice fields in rotation and runoff water from fallow fields, while gravity-based recovery involves the use of pipes or ditches to divert drain water to adjacent fields. The amount of water available for capture depends on the water balance in each field. Water loss for a reservoir-based recovery system includes loss during the transport of tailwater to and from the reservoir, evaporation from the reservoir surface, percolation, and seepage.

Water Savings of Different Conservation Technologies

A project jointly sponsored by the Lower Colorado River Authority and the San Antonio Water System from 2004 through 2009 evaluated the water savings and costs associated with implementing different on-farm water conservation measures (Yang *et al.* 2012). Table 8a presents a summary of the water savings for each conservation technology.

District Water Saving refers to water saving associated with conservation improvements distributed to all fields in an irrigation district. *Field Level Water Saving* refers to water saving involving only those fields that implemented a specific conservation technology. District water saving is less than field level water saving in situations when some fields in the district have already adopted a specific conservation technology and only the remaining fields could be further improved.

Economics of Different Conservation Technologies

The costs of implementing conservation improvements include soil movement for precision leveling; irrigation pipes, water gates and their installation for multiple inlet systems; cultivation and herbicide-based weed control for conservation tillage; underground pipes and their installation or weed control for lateral improvement; and reservoir construction, irrigation pumps, pipes, and value of land that is lost for tailwater recovery systems, and maintenance and operation costs for each conservation measure.

Table 8a. District and field level water savings associated with conservation improvements.

Conservation Measure	District Level Water Saving (ac-in/ac)			Field Level Water Saving (ac-in/ac)		
	Lakeside	Gulf Coast	Garwood	Lakeside	Gulf Coast	Garwood
Contour to Bench	1.5	2.4	1.7	3.8	3.9	4.0
Contour to Constant	0.4	1.1	0.5	1.0	1.8	1.2
Constant to Bench	1.4	0.9	1.6	2.6	2.3	3.3
Multiple Inlet	3.7	3.3	4.1	4.0	3.7	4.4
Conservation Tillage	1.7	1.8	2.0	1.9	2.0	2.3
Underground Pipe	0.7	0.7	3.6	0.7	0.7	3.6
Tailwater Recovery	11.0	18.6	12.0	11.0	18.6	12.0
High Yield Variety	11.4	11.1	17.0	11.4	11.1	17.0

An economic model for on-farm water conservation technologies was developed as a part of the joint project sponsored by the Lower Colorado River Authority and the San Antonio Water System (Wilson et al. 2016). Precision leveling provides the best overall economic benefit for all three districts (Lakeside, Gulf Coast, and Garwood). Growing high-yielding varieties offers the greatest yield benefit for Gulf Coast, which has a low ratoon crop percentage, but results in the greatest yield loss for Garwood, which has the highest ratoon crop percentage, assuming no ratoon crop production. Tailwater recovery systems and growing high-yielding water-efficient varieties save the most water. However, water conservation measures that save the most water are not necessarily the most cost effective or are still in limited availability. For example, tailwater recovery systems are very costly to construct, and unless subsidized by USDA Environmental Quality Incentives Program, the cost may be prohibitive. Similarly, high-yielding water-efficient varieties are limited and mostly in the development stage.

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Nitrogen Management

F. Dou and L. Tarpley

Research and experience have shown that there is a great deal of flexibility in how Texas rice farmers can manage their fertilizer programs, provided that the basic nutrient requirements are met. These suggestions provide basic information upon which a farmer can build an economical rice fertilizer program that can be adjusted to fit specific field situations.

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Fertilizer management can profoundly influence rice yield, and it is a major cost for rice production. Therefore, a critical review of fertilizer practices can mean increased income without sacrificing yields.

For maximum net profit, apply only those fertilizers needed for maximum economic yields. Of the three major supplied nutrients (nitrogen, phosphorus and potassium, or N, P and K), nitrogen affects rice yield in Texas the most.

Nitrogen Sources

Although rice can use ammonium and nitrate sources of nitrogen, under flooded conditions, the nitrate form is unstable and is lost from the soil by leaching and denitrification (a microbial process that converts nitrate to nitrogen gas). However, ammonium nitrogen (urea and ammonium sulfate) is stable when placed below the flooded soil surface away from air and can be used by the rice plant. Ammonium on the soil surface or in floodwater gradually changes to nitrate and is lost by denitrification. Ammonium sulfate and urea sources of ammonium are much more efficient than nitrate nitrogen sources for rice.

If the fields are drained for several days, urea and ammonium sulfate can be converted to the nitrate nitrogen form. Upon flooding the soil, the nitrate nitrogen is lost primarily through denitrification. Therefore, to conserve and maintain nitrogen efficiency, nitrogen fertilizer should be incorporated or flushed into the soil with irrigation water and the soil should remain water saturated or as moist as possible.

Another way to increase nitrogen efficiency is to use banded fluid fertilizer. Research has shown that applying fluid fertilizer in a band 2 to 3 inches below the soil surface can improve N uptake in rice compared to dry broadcast fertilizer. However, concerns about banding fluid fertilizer include the skill required to apply the fertilizer uniformly over the field, the initial cost of application equipment, the time required to fill fertilizer tanks, and the time required to apply the fertilizer. To reduce application costs, attach the fluid applicator knives to the seed drill, which allows 75 to 100 percent of the total N plus P and K to be applied while planting. In addition, establishing a flood at the four-leaf growth stage rather than at the six-leaf or later stage maximizes the efficiency of banded fluid fertilizer uptake.

For preplant or Initial Fertilizer Application, apply nitrogen fertilizer just before planting, at planting, or before the three-leaf stage of rice growth. To increase nitrogen use-efficiency, incorporate or drill preplant fertilizer into the soil. If the initial fertilizer application is made at

planting or before the three-leaf stage of rice growth, be sure the application is on dry soil and the field is flushed as soon as possible to move the fertilizer into the root zone. When the fertilizer (urea) will lay on the soil surface for 2 to 7 days before being flushed into the soil, application of a urease inhibitor is recommended to reduce N loss associated with ammonium volatilization, especially for coarse soils or soils with high pH value.

After seedling emergence and initial fertilizer application, keep the soil moist until time for the pre-flooding application. If weed populations are high, a post-emergence nitrogen application may be more economical than a broadcast preplant application because it does not stimulate early weed growth.

To gain the most from preflood nitrogen application, apply the nitrogen on dry soil just before flooding and allow the floodwater to carry the fertilizer away from the air and into the root zone where it has more protection from loss. If urea is applied and a permanent flood cannot be established in two days or less for sandy loam soils or seven days or less for clay soils, the urea needs to be treated with a urease inhibitor, e.g., N-(n-butyl) thiophosphoric triamide (NBPT) (i.e., Agrotain), to avoid N loss. On the other hand, if the soil is so wet just before flooding that the floodwater will not carry fertilizer nitrogen into the soil, establish the flood and apply 50 percent of the preflood nitrogen in the floodwater and the remaining 'preflood' nitrogen 10 days later. Applications in floodwater reduce or eliminate fertilizer streaks, but up to 20 percent or more of the applied nitrogen may be lost. A field trial using a hybrid, XP753, conducted in 2020 showed the effect of soil moisture condition prior to preplant N application on rice yields and milling quality (Table 9a).

Table 9a. Influence of sub-optimal soil moisture condition and nitrogen source on rice main crop grain and milling yields of XP753 at the Beaumont Center during 2020.

Preflood		Panicle differentiation	Late booting	Total N	Main crop (lb/acre)	Whole grain (%)	Total grain (%)
Dry soil	Flooded Soil						
Agrotain coated urea N (46%)							
150	0	0	30	180	9,827a	63.6a	71.9a
0	90	60	30	180	8,491ab	59.4b	71.6a
0	60	90	30	180	6,460c	57.6b	70.8a
0	150	0	30	180	7,843bc	58.4b	71.2a
Ammonium sulfate N (21%)							
150	0	0	30	180	8,520a	60.4a	71.9a
0	90	60	30	180	7,579b	59.5a	71.9a
0	60	90	30	180	7,164b	57.7b	71.8a
0	150	0	30	180	7,844ab	60.7a	72.1a
0	0	0	0	0	4,128c	48.7c	70.8b

Two nitrogen fertilizers: urea coated with the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) (i.e., Agrotain) and ammonium sulfate, were applied either on dry soil or into

flood water. At late booting stage, all plots received 30 lb N/acre except the control, which received no fertilizer N. Urea and ammonium sulfate applied on dry soil produced the highest main crop grain yields at both locations (Tables 9b-c). Rice grain yield was significantly lower when the same fertilizer N was applied into flood water. Even with the elevated N rates (30 lbs/acre more), the grain yields were still significantly lower in most cases. Rice milling yields were also affected by the apparent N loss associated with soil moisture conditions. The milling yield was higher for the treatments with N fertilizer applied on dry soils (Table 9c).

Table 9b. Influence of sub-optimal soil moisture condition and nitrogen source on rice main crop, ratoon crop, and total crop yields of XP753 at the Eagle Lake Station during 2020.

Preflood							
Dry soil	Flooded Soil	Panicle differentiation	Late booting	Total N	Main crop	Ratoon crop	Total (main + ratoon) crop
Agrotain coated urea N (46%)							
120	0	0	30	150	10,816 a	4,238 a	15,054 a
0	120	30	30	180	9,582 b	3,882 a	13,464 b
0	90	60	30	180	9,075 b	3,771 a	12,846 b
0	150	0	30	180	9,030 b	3,653 a	12,683 b
0	120	0	30	150	8,827 b	4,211 a	13,038 b
Ammonium sulfate N (21%)							
120	0	0	30	150	10,684 a	4,646 a	15,330 a
0	120	30	30	180	9,931 ab	4,458 ab	14,388 b
0	90	60	30	180	9342 b	4078 b	13,691 c
0	150	0	30	180	9,559 ab	4,252 ab	13,812 bc
0	120	0	30	150	9,152 b	4,608 a	13,760 bc

Table 9c. Influence of sub-optimal soil moisture condition and nitrogen source on rice main crop milling yields of XP753 at the Eagle Lake Station during 2020.

Preflood		Panicle differentiation	Late booting	Total N	Whole grain (%)	Total grain (%)
Dry soil	Flooded Soil					
Agrotain coated urea N (46%)						
120	0	0	30	150	64.4 a	71.6 a
0	120	30	30	180	62.4 a	71.0 b
0	90	60	30	180	62.5 b	70.9 b
0	150	0	30	180	62.0 b	70.9 b
0	120	0	30	150	62.8 b	71.3 ab
Ammonium sulfate N (21%)						
120	0	0	30	150	64.1a	71.5 a
0	120	30	30	180	63.8 ab	71.2 a
0	90	60	30	180	63.8 ab	71.5 a
0	150	0	30	180	63.7 ab	71.3 a
0	120	0	30	150	62.5 b	71.0 a

PD (Panicle Differentiation) or Midseason Application

If the rice plants appear nitrogen-deficient, apply nitrogen before the PD stage. If fields are very uniform in stand emergence (emergence within 2 days), applications earlier than PD might be warranted. The PD application is made when 30 percent of the main stems have 2 mm or longer panicles. This application is efficiently used (taken up within 3 days) by plants because the roots cover the flooded soil surface.

The following recommended nitrogen timings consistently provide maximum economic yield over a wide range of soil types and planting dates.

March plantings (three applications)

- Apply about 20 to 25 percent of the nitrogen just before planting or by the three-leaf stage of rice growth.
- Apply 35 to 40 percent on dry soil just before flooding.
- Apply 40 percent at PD or before if needed.

April plantings (three applications)

- Increase early-season nitrogen applications over those for March plantings. April plantings usually grow faster because of the warmer temperatures and require more nitrogen early

- Apply about 1/3 of the nitrogen at each of the three application times.

May plantings (two applications)

- Apply about 2/3 of the nitrogen just before planting
- Apply the remaining 1/3 at PD or earlier if needed to correct nitrogen deficiencies.

Nitrogen Application Rates

Nitrogen requirements for rice vary depending on location, planting date, variety, water management and soil conditions. Because soil N availability is often time consuming to estimate, the recommended nitrogen rates for each rice variety (Table 9d) are often determined by nitrogen fertilizer response in research tests. Do not delay nitrogen topdressing when plants become nitrogen deficient, as the yield potential of the semidwarf varieties drops each day the plants exhibit nitrogen deficiency (yellowing). Make further adjustments in nitrogen management, recognizing that early-planted rice grows slowly in cool temperatures and may require 5 to 15 more lb/ac of nitrogen over the season than late-planted rice. If a field has a history of severe lodging or has not been cropped recently, reduce the suggested nitrogen rates.

Table 9d. Main crop nitrogen requirements (lb N/ac) for specific varieties on various soil types.

Variety	Western rice belt[a]		Eastern rice belt	
	fine (clay)	coarse (sandy)	fine (clay)	coarse (sandy)
Long grain inbred rice[a]	210	180	210	180
Hybrid rice[b]	150	120	150	150

[a]Nitrogen recommendations for long-grain inbreds are from the results of replicated field trials conducted at the Eagle Lake Station and Beaumont Research Center.
[b]RiceTec's nutrient recommendations (https://www.ricetec.com/products-services/).

If rice is to follow grain sorghum or corn in rotation, shred or disk the grain sorghum or corn stubble immediately after harvest to decrease the nitrogen immobilization during the growing season. Depending on the rate of straw decomposition, the immobilized nitrogen will become available to the rice plants at a later growth stage.

Symptoms and characteristics of nitrogen deficiency include the following:

- Rice growing in the paddies between the levees is lighter green than rice growing on the levees
- Rice between levees has dark green areas as well as light green areas
- Plants growing in the levees have yellowish lower (older) leaves with possible brown tips, and green upper (younger) leaves with yellow tips

Ratoon Crop Management

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Ratooning (second cropping) of rice is a production strategy for double cropping in temperate regions like the U.S., with the objective of increasing income per unit area in the same cropping year. Ratooning typically involves low production costs since it requires relatively little labor, water, or other production inputs such as herbicide and pesticide. The ratoon crop matures more quickly than the main crop and often yields about half or more compared to the main crop. High ratoon yield depends on an appropriate variety, establishment of a good ratoon stand, short stubble height, applied fertilizer and water management, control of diseases, insects, and weeds, high main crop plant density, uniform plant spacing, and thorough field preparation.

Typically, the earlier the ratoon crop matures, the higher its potential yield. Therefore, rapid stimulation of regrowth is an important factor. Apply the planned pre-flood nitrogen immediately after harvesting the main crop and flood it into the soil to stimulate regrowth. Keep soils moist with a shallow flood until regrowth has advanced and re-tillering has established. After re-tillering, maintain a flood sufficient to control weeds. In addition, maintaining a flood prevents sugarcane beetle from attacking the culms and roots of ratoon rice. Fields should not be flushed after harvest. Flushing permits the germination of rice grain residue from harvesting. These germinated rice seeds become weeds that compete for nutrients and light, but time does not permit them to produce panicles. Flooding immediately after main crop harvest prevents the germination of these seeds through the formation of an anaerobic layer near the soil surface.

Varietal Selection

Ratoon crop yield varies with variety (see the Varietal Selection chapter for greater detail). Among the released varieties, Presidio exemplifies high ratoon yield potential for inbred varieties, often yielding more than 5,000 lb/ac ratoon. Several other inbred varieties have good ratoon yield-potential, but reports indicate that many hybrids have relatively better ratoon yield potential. Generally, early maturing varieties are preferred because they allow an earlier start to the ratoon crop and thus the ability to harvest the crop before the onset of the winter season. The selected variety should have resistance to prevailing diseases and insects that can build up their populations on the main crop and move to the ratoon plants. If not, additional pesticides, with their associated costs, may be needed. Development of new tillers is very important in ratooning. A variety should produce ratoon tillers from basal (crown) buds starting as early as the soft dough stage of the main crop and not later than immediately after harvest, but not too early such as before or during early grain development of the main crop. These very early ratoon tillers do not contribute to the yield of either crop. The stem should be green and not brown or dry at harvest. Selected varieties should display slow leaf senescence since this can delay the drying of the stem and its dormant buds critical in fully developing ratoon tillers. The number of tillers in the main crop and the number of dormant buds per tiller are important traits since these will affect the number of panicles, a determinant of grain yield. Tolerance to low temperature and drought at the reproductive stage are also important traits during ratooning.

Stimulating Ratoon Tiller Regrowth with Gibberellic Acid

Development of dormant buds into tillers should commence immediately after harvest or preferably as early as the main crop soft dough stage. Development should be uniform to obtain a combination of high grain yield and milling quality. Gibberellic Acid (GA) can promote ratoon tiller growth. Ratoon crop yield increases commonly occur in response to a GA treatment of 4 grams (0.009 pounds) active ingredient per acre applied to the main crop from several days past peak flowering to the soft dough stage. The very early maturing hybrids, such as XL723, appear to be especially responsive to GA treatment with an average ratoon yield increase of 622 pounds per acre in research studies over several years. The yield increase appears to be a result of enhanced early growth of the ratoon tillers, which provides earlier ratoon stand establishment. Main crop yield and main and ratoon crop milling qualities do not appear to be affected by the treatment. The GA application, however, slightly delays, by 1 to 2 days, main crop development. This needs to be considered when planning harvests of main crop fields.

The GA application at the soft dough stage has the potential additional advantage that it can be tank-mixed with insecticide applications applied during grain filling. This would save on application costs and provide an economical way of increasing yields. Studies conducted at the Beaumont Center show no loss in efficacy of either compound when GA and a pyrethroid were applied together at this growth stage. Although there is no known negative effect from later GA applications up to the main crop harvest, the benefit gained from enhancing early growth of the ratoon tillers would often be diminished.

GA applied during stem elongation can enhance elongation, thus increasing plant height and the potential for lodging. Avoid early applications of GA to tall varieties that may still be undergoing stem elongation during early grain filling. Application during peak flowering can sometimes decrease main crop yield, according to research at the LSU AgCenter; therefore, GA should be applied after peak flowering. The GA treatment's likelihood of benefit decreases with disease or nutritional stress on the ratoon crop. This treatment is applied to the main crop to benefit ratoon crop yield.

Most on-farm trials of the GA treatment show an increase in ratoon crop yield. Given the low cost of GA and the low risk involved, this treatment can be considered as an "insurance" to be used as a tank-mix addition to insecticides applied during main crop grain filling.

Main Crop Cutting Height

Traditionally, the main crop was cut at about 18 inches above the ground (depending on variety). Ratoon tillers may be generated at any node below the height of cutting. Panicles from aerial nodes tend to be smaller with smaller grain compared to tillers originating from the crown and mature very quickly. Panicles from the crown are usually larger but mature much later. Panicles from nodes at different positions may increase variability in maturity and decrease milling yield. Plot research and field verification tests have shown that reducing the cutting height will increase ratoon crop yield and uniformity. In small plots, yield increases as main crop cutting height decreases to 4 inches. Yields do not increase below 8 to 10 inches in field verification tests. The lower main crop cutting height eliminates aerial nodes and promotes the establishment of more uniform, higher yield potential tillers from the crown. Reducing main crop cutting height delays ratoon crop maturity by 10 or more days. This delay can be partially offset by making a nitrogen application

about 7 days before main crop drain and flooding immediately after harvest. The reduced cutting height can be achieved during combining or by using a flail shredder. **Note: If your ratoon crop is late, you may not want to use a low cutting height.** Finally, recent research conducted in Texas suggests decreasing main crop cutting height reduces populations of stalk borers attacking the ratoon crop. The mowing operation kills many stalk borer larvae and pupae in the main crop stubble. Thus, many larvae in the stubble are prevented from moving over to infest new ratoon tillers, and many pupae in the stubble are unable to complete development reducing the number of egg-laying moths.

The good chop obtained when using a flail shredder to achieve the shorter stubble height promotes ratoon stand density and vigor, primarily by minimizing straw matting and windrowing, which can either physically inhibit the developing tillers or shade them excessively. The smaller chop size obtained when flailing may further decrease stalk borer larvae and pupae populations.

Ratoon Crop Nitrogen Fertilization

The recommended nitrogen rate for ratoon crop production is dependent on the anticipated yield potential. Maximum ratoon crop yield potential occurs when there is: 1) main crop harvest before August 15, 2) absence of disease in the main crop, 3) limited field rutting by equipment, and 4) good weed control in the main crop. If all or most of these conditions can be met, application rates of 60 to 100 pounds of nitrogen per acre are recommended. The specific nitrogen rate depends on variety, yield target, and economics. Decrease or eliminate nitrogen application if the main crop harvest is delayed, ratoon tillers are few, disease is present, fields are rutted, or weed pressure is significant. Remember, any delay in nitrogen and water application reduces the yield potential of ratoon crop rice.

Nitrogen Timing on Fine (Heavy) Soils

Splitting ratoon crop nitrogen by applying 1/3 to 1/2 at 10 to 15 days after main crop heading and the remainder immediately after main crop harvest has not consistently increased yields of the ratoon crop. If nitrogen deficiency occurs during the late stages of main crop development, top dressing of the main crop at this time may hasten ratoon crop tiller development and maturity. However, a near-heading application on a main crop that has sufficient nitrogen can produce excessive green foliage at main crop harvest.

Nitrogen Timing and Water Management on (Light) Coarse Soils

Several years of research data on a coarse soil at Eagle Lake suggest that when this type of soil remains dry for approximately 20 days between main and ratoon crops, ratoon crop yields can be increased by splitting the ratoon crop nitrogen (i.e., applying 1/2 to 2/3 immediately after harvest and the remainder 25 days after ratoon flood). However, if the ratoon crop flood is delayed more than 10 days after the main crop harvest, splitting the ratoon crop nitrogen does not increase ratoon crop yields. A dry period longer than 30 days between main crop drain and ratoon crop flood can devastate ratoon crop yields on coarse soils. A dry period of 10 days or less can reduce ratoon crop yields, indicating that coarse soils, such as those at Eagle Lake, need a dry period of 15 to 20 days and split nitrogen application to achieve optimum yields. Splitting ratoon crop nitrogen does not increase yields when the dry period between the main and ratoon crops is greater than 25 or less than 10 days.

Weed Management

Herbicide use for broadleaf weeds, particularly dayflower, is the biggest concern in ratoon crop rice. Several herbicides are currently labeled for use in ratoon crop rice. These include 2, 4-D, Grandstand R®, and Basagran®. Check the label for rates, timing and weeds controlled.

Disease Management

Narrow brown leaf spot (also called Cercospora leaf spot) is the most important disease affecting ratoon crop production in Texas, although several other diseases can cause severe damage to the ratoon crop when conditions are favorable for their development. Planting with a resistant variety is the most effective means to control narrow brown leaf spot in the main and ratoon crops. Varieties with a high level of resistance to the disease are available, although its severity has continued to increase over the last two decades. See the disease resistance rating table in the Disease Management chapter. In addition, proper timing of fungicide application on the main crop can improve ratoon crop yield and milling quality. Small field plot studies show an increase of up to 13% in ratoon crop yield and significant head rice milling quality improvement when a single propiconazole-containing fungicide application is made between the boot stage and up to 7 days after main crop heading. Fungicides that contain propiconazole, fluxapyroxad (Sercadis®), or difenoconazole (Amistar Top®) as an active ingredient are most effective for managing this disease. These propiconazole-containing fungicides include Bumper®, PropiMax®, Stratego®, Tilt®, Quilt®, and QuiltXcel®. Be aware that propiconazole-containing fungicides are not labeled for use on the ratoon crop. Amistar Top®, which contains azoxystrobin and difenoconazole, is the only fungicide that is labeled for use in the ratoon crop. Check the labels for legal use, rates, and timing.

Sheath blight develops in the main crop but usually not in the ratoon crop due to lower temperatures. No fungicides are currently recommended for the control of sheath blight in the ratoon crop. However, good control of sheath blight with fungicides on the main crop is recommended, which can increase ratoon crop tiller density, resulting in an additional yield increase. See the Disease Management chapter for more information on fungicide treatments of sheath blight in the main crop.

Insect Management

In general, control of insects in the main crop results in increased yields in the ratoon crop. Texas data consistently show economic returns for the ratoon crop when rice water weevil and stalk borers are controlled in the main crop. Control of these insects results in improved vigor and increased tiller production in the ratoon crop. Also, recent research shows the positive effects of insecticidal seed treatment carry-over to the ratoon crop. Thus, farmers who plan to ratoon crop should seriously consider planting seed treated with an insecticide.

Management of rice stink bug is similar on main and ratoon crop rice. For the ratoon crop, use the same sampling techniques, treatment thresholds and insecticides/timings/rates as described in the Insect Management chapter. However, ratoon crop maturity is usually not very uniform. Thus, a field of ratoon rice can have panicles emerging and grain in the dough stage simultaneously. This makes the timings of insecticide applications problematic. To address this problem, farmers should consider applying insecticides with residual activity to control rice stink bugs. See the Insect Management chapter for information on rice stink bug insecticides and their properties.

PEST MANAGEMENT

Weed Management

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Weeds are one of the major factors limiting the production of rice in Texas. Weeds reduce rice grain yield and quality by competing for nutrients, light, water, and space. Weed competition, especially in the seedling stage, can significantly affect rice plant growth and development, which can cause yield loss of more than 50%. Rice is especially susceptible to weed competition prior to permanent flood establishment. Effective management of weeds during this time is critical to maximizing yield.

Several weeds have adapted to rice production systems worldwide, with more than 70 weed species infesting rice fields in the U. S. Many grasses, broadleaf weeds and sedges can cause significant damage to rice. Barnyardgrass, broadleaf signalgrass, sprangletops, johnsongrass, hemp sesbania, annual and perennial sedges, and several aquatic species such as alligatorweed are among the most economically important weed species in drill seeded rice in the southern U.S.

General Weed Management Practices

The best approach to controlling weeds in rice involves a combination of good cultural, mechanical, and chemical practices. Cultural and mechanical practices include:

- Using certified seed that is relatively free of weed seed
- Clean equipment when moved between multiple fields
- Using crop rotations and preparing a good seedbed to eliminate all weeds before planting rice
- Leveling land in combination with good water management
- Developing weed maps or records for individual fields as an aid in determining which herbicides can be used most effectively targeting specific weed species

With the semidwarf varieties, it is particularly critical to maintain good early season weed control because early competition from weeds can significantly reduce rice yield. Therefore, it may be advisable to use a residual herbicide at planting to obtain good initial weed control.

Residual herbicides applied in combination with post-emergence herbicides provide good to excellent control of emerged weeds and an additional 4 to 6 weeks of residual control of susceptible species. Because they are soil-active, applying residual herbicides at improper rates can result in long-term rice injury and/or poor weed control. Certain herbicides have label restrictions associated with methods of planting and limitations related to soil texture and water management.

Weedy (Red) Rice Management

Weedy rice includes red rice (with red seed kernel) and several other biotypes. Controlling weedy rice requires a management approach that uses a combination of preventive practices, cultural, and herbicide control.

Preventive Practices - Preventive measures include planting certified rice seed (weed-free) and using clean equipment and machinery in farm operations. The use of rice seed free of weedy rice is extremely important in preventing the introduction of weedy rice into a field. After working a field infested with weedy rice, whether during field preparation or harvesting, clean machinery before moving to the next field to prevent the introduction of weedy rice seed into other fields. Mud and other debris that clings to tractors and cultivating equipment can contain weedy rice seed that can be moved into a weedy rice-free field.

Cultural Control - In addition to preventive practices, certain cultural controls can be used. During seedbed preparation, it is important to destroy all weedy rice plants in the field before planting. Because weedy rice is more vigorous and grows faster than most commercial rice, commercial rice should be given an opportunity to compete effectively with weedy rice by planting it at the recommended or slightly higher seeding rate. Weedy rice tillering and seed production is decreased when competition from commercial rice is high. Use proper water management to suppress weedy rice effectively. Permitting soil to cycle (dry out and rewet) encourages the germination of weedy rice and other weeds.

Water-seeding in combination with good water management helps suppress weedy rice. Two suggested techniques are continuous flood culture and the pinpoint flood system (see the Water Conservation and Management chapter). In these two systems, it is important to flood immediately after seedbed preparation. A delay in flooding allows weedy rice seed to germinate and become established before flooding, resulting in a reduction of weedy rice suppression by flooding.

Post-harvest management is critical in weedy rice management. Weedy rice seed incorporated into a high soil moisture zone in the soil may remain dormant for longer periods than those left on the soil surface over winter. These seed will germinate by March and can be killed by cultivation. Weedy rice will also lose its dormancy through a series of wetting and drying cycles. A winter with alternating dry and wet periods most likely will result in severe weedy rice pressure in the following season. A wet winter generally results in lower weedy rice pressure the next season.

Herbicide Control - Although both continuous and pinpoint flood systems suppress weedy rice, they may not provide adequate control. To improve control, use herbicides in combination with specific water management techniques.

Newpath® can be applied only to CLEARFIELD® rice varieties and provides very effective control of weedy rice. Two applications are critical for control. The first application can be applied preplant and incorporated or at spiking to one leaf rice or weedy rice. The later postemergence application has proven to provide better control. The second application should be applied at four-leaf rice or weedy rice. Applications made later (five- to six-leaf) may reduce control.

The herbicide must be activated immediately after application with a flush or rainfall to facilitate residual activity in the soil. The best control is obtained when the flood is applied no later

than 7 days after the last application. Field selection is critical. Non-CLEARFIELD® rice fields and other crops are extremely sensitive to drift. Weed escapes can occur. In the CLEARFIELD®/Newpath system, Beyond® at 5 oz per acre can be used to control escapes. Beyond® can be applied between late tillering and panicle initiation. Beyond® can be applied only following two applications of Newpath®. It is strongly recommended that escapes be rogued from fields before heading.

The PROVISIA® Rice System provided farmers with another effective tool to control weedy rice, including rice volunteers that are resistant to herbicides such as Newpath® and Beyond®, and grasses with multiple herbicide resistance. PROVISIA® is a companion system to the CLEARFIELD® Production System for rice. The PROVISIA® Rice System is comprised of the Provisia resistance trait that allows farmers to safely apply Provisia herbicide. Farmers can use the PROVISIA® Rice System in rotation with the CLEARFIELD® Production System for rice to maximize weed control and minimize the development of herbicide resistance.

FullPage Rice Production System consists of imidazolinone (IMI)-tolerant rice and IMI herbicides to improve weed control and provide herbicide application, timing, and flooding flexibility. RT7321 FP, RT7521 FP, RT7421FP and RT7523FP are the four FullPage hybrid varieties released. FullPage rice is paired with Preface (imazethapyr) and Postscript (imazamox) herbicides. Preface has post-emergence and residual activities and can control troublesome weeds such as red rice, weedy rice, and barnyardgrass. Postscript can be applied post-emergence or post-flood to control any escapes.

The Max-Ace rice cropping system is the combination of the Max-Ace trait exclusive to RiceTec and the Highcard herbicide specifically designed to be used with Max-Ace Rice Cropping Solution manufactured by Adama. The RiceTec RTv7231 MA variety and hybrid RT7331 MA were available for the 2022 cropping season.

It is extremely important to make sure that Provisia herbicide is applied only to Provisia® rice varieties. It can be two sequential applications made from 1-leaf stage up to panicle initiation. The 2nd application should be made prior to panicle initiation for complete control of weedy and volunteer rice due to extended emergence. The two sequential applications should be separated by at least 10 days. Total active ingredient (a.i.) of no more than 31 ounces per acre (0.21 lb a.i./ac) per year is allowed. Provisia can be applied mixed with other herbicides, but antagonism may occur. Farmers need to refer to the label for approved mixture applications.

Stale Seedbed Technique - Another method of weedy rice control is to use the fall or spring stale seedbed cultural management system as described in the Land and Seedbed Preparation chapter. Keep it idle or stale to allow germination and growth of weedy rice. If necessary, fields may be flushed to maximize weedy rice seed germination.

When weedy rice is actively growing and 4 inches tall or less, apply 1 quart of 4 lb a.i./gal glyphosate. When applying by air, use 3 to 5 gallons of water per acre. Application to weedy rice growing in saturated soils is not as effective as in moist soils. Normal production practices are then followed. For the most effective control of weedy rice, wait at least 6 days but not more than 9 days after application to flood and plant using the water-seeded method.

Crop Rotation - The most practical and economical way to control weedy rice is to rotate rice with grain sorghum or soybeans. Two suggested 3-year crop rotations are rice/grain sorghum/soybean or rice/soybean/soybean. When growing soybean in these rotations, use an herbicide such as Prowl®, Lasso®, Dual Magnum® or Treflan® at recommended label rates. Planting grain sorghum in the rotation and using atrazine is also effective. Although weedy rice can be controlled with these herbicides, early cultivation, and application of a selective post-emergence soybean herbicide such as Poast Plus®, Select®, Assure® II or Fusilade® DX are necessary to control any weedy rice that escapes the soil-applied herbicide. It is important to plant alternative crops for at least 2 years prior to rice to achieve satisfactory control of weedy rice.

Herbicide Use Recommendations and Comments.

Selecting an effective herbicide is the key to successfully managing weeds in rice. Tables 11a and 11b list the relative weed control efficacy ratings for rice herbicides. Table 11c shows a chronological list of herbicides available for rice with suggested application rates and comments. Read the labels for specific instructions and precautions.

Table 11a. Weed response ratings for rice herbicides.

		Weeds and control																				
Herbicides	***Active Ingredient***	**Barnyardgrass**	**Crabgrass**	**Signalgrass**	**Sprangletop**	**Red rice**	**Johnsongrass**	**Nutsedges**	**Flatsedges**	**Spikerush**	**Ammania (redstem)**	**Dayflower**	**Ducksalad**	**Eclipta**	**Gooseweed**	**Jointvetchs**	**Morningglories**	**Hemp Sesbania**	**Smartweed**	**Water-hyssop**	**Texasweed**	**Alligatorweed**
PREPLANT BURNDOWN																						
2,4-D	*2,4-D*	U	U	U	U	U	U	P	U	U	E	F	G	E	U	E	E	E	U	E	E	G
FirstShot	*Thifensulfuron + Tribenuron*	U	U	U	U	U	U	P	U	U	P	-	F	F	U	G	F	G	E	-	-	E
Gambit	*Halosulfuron + Prosulfuron*	U	U	U	U	U	U	E	G	G	E	G	E[4]	E	G	E	E	E	E	G	G	G[3]
Gramoxone SL	*Paraquat*	E	G	E	E	G	G	P[1]	F	F	E	F	F	E	F	E	G	E	U	F	E	P
Grandstand R	*Triclopyr*	U	U	U	U	U	U	P	G[3]	G	E	F	F	G	-	E	E	E	U	G	E	E
LeadOff	*Rimsulfuron + Thifensulfuron*	G	G	U	F	P	F	P	P	-	-	-	-	-	-	F	U	F	G	-	-	-
Permit/ Halomax	*Halosulfuron*	U	U	U	U	U	U	E	G	G	E	G	E	G	G	E	F	E	P	E	G	U
Permit Plus	*Halosulfuron + Thifensulfuron*	U	U	U	U	U	U	E	G	G	E	G	E	G	G	E	G	E	E	E	G	F
Glyphosate	*Glyphosate*	E	G	E	E	F	F	F	F	F	E	P	F	G	F	F	F	F	P	F	E	F
Sharpen	*Saflufenacil*	U	U	P	P	P	U	P	U	U	E	F	G	G	F	G	G	G	F	E	G	F
PREPLANT, PREEMERGENCE or DELAYEDPRE																						
Bolero PRE[2] or DELPRE	*Thiobencarb*	F	E	P	E	U	P	U	F	F	G	G	G	G	F	P	U	U	U	G	P	U
Command, Up-Stage, Caravel	*Clomazone*	E	E	G	G	U	E	U	U	U	U	F	F	U	U	U	U	U	U	U	U	U
Facet L, Zurax L, Quinstar 4L	*Quinclorac*	E	E	E	U	U	P	U	U	U	U	P	U	G	U	F	G	F	P	F	U	U
Quinclorac + Bolero	*Quinclorac + Thiobencarb*	E	E	E	F	U	P	P	P	F	F	G	F	G	F	G	G	F	P	F	P	U
Gambit	*Halosulfuron + Prosulfuron*	U	-	U	U	U	-	E	E	-	E	G	E	E	-	E	E	E	E	F	G	G
Obey	*Clomazone + Quinclorac*	E	E	E	G	U	E	U	U	U	U	F	F	G	U	G	G	G	U	F	U	U

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League PRE[2] or DELPRE	*Imazosulfuron*	U	U	U	-	U	U	E	G	-	-	E	F	G	-	G	G	G	-	-	E	U
Permit	*Halosulfuron*	-	U	U	F	U	U	E	-	U	U	E	U	-	U	-	U	U	E	U	U	U
Permit Plus	*Halosulfuron + Thifensulfuron*	U	U	U	U	U	U	E	G	U	E	G	F	G	U	G	F	E	G	P	P	P
Pendimethalin DELPRE	*Pendimethalin*	G	E	E	E	U	G	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Strada XT2	*Orthosulfamuron + Quinclorac*	E	E	E	U	U	U	G	E	-	E	G	F	E	-	E	G	E	F	G	F	F
RiceOne DELPRE	*Pendimethalin + Clomazone*	E	G	E	G	U	-	U	U	-	U	F	F	U	-	U	U	U	U	U	U	U
Sharpen	*Saflufenacil*	U	U	U	U	U	U	P	P	U	P	F	U	F	-	F	G	F	P	P	F	U
POSTEMERGENCE																						
2,4-D	*2,4-D*	U	U	U	U	U	U	P[1]	U	U	E	G	E	E	-	F	E	E	P	E	E	G
Aim[3]	*Carfentrazone-Ethyl*	U	U	U	U	U	U	P	U	U	F	F	P	F	U	G	E	E	G	G	F	P
Aim + Grandstand	*Carfentrazone-Ethyl + Triclopyr*	U	U	U	U	U	U	U	U	U	E	F	P	G	F	E	E	E	G	G	F	G
Basagran	*Bentazon*	U	U	U	U	U	U	E[5]	G	G	G	E	E	G	F	U	F	U	F	G	U	U
Blazer	*Acifluorfen*	U	U	U	U	U	U	U	U	U	E	U	U	U	U	U	F	E	U	U	P	U
Clincher[2]	*Cyhalofop*	E	G	G	G	U	G[6]	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Duet (Propanil + Londax)	*Propanil + Bensulfuron Methyl*	G	G	E	F	U	U	G	E	E	E	G	G	E	E	E	E	E	F	G	G	F
Facet L, Zurax L, Quinstar 4L	*Quinclorac*	E	E	E	U	U	U	U	U	U	U	U	U	E	U	G	G	P	U	P	P	P
Gambit	*Halosulfuron + Prosulfuron*	U	-	U	U	U	-	E	E	-	E	G	E	E	-	E	E	E	E	F	G	G

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Grandstand R[7]	*Triclopyr*	U	U	U	U	U	U	P	U	U	G	F	U	F	G	G	E	F	P	G	G	F
Grasp	*Penoxulam*	E	U	U	U	U	U	G	E	G	F	G	G	G	U	E	P	G	G	G	G	F
GraspXtra	*Penoxulam + Triclopyr*	E	U	U	U	U	U	G	E	G	E	G	G	G	F	E	E	E	E	E	G	G
League	*Imazosulfuron*	U	U	U	U	U	U	G	G	-	G	E	F	G	-	G	G	G	G	F	E	P
Londax[2]	*Bensulfuron Methyl*	U	U	U	U	U	U	F	G	G	G	G	G	G	G	F	P	P	P	G	G	P
Loyant	*Florpyrauxifen-Benzyl*	F[4]	-	F[4]	F[4]	U	-	G	G	G	G	G	E	E	-	E	E	E	E	G	U	E
Obey	*Clomazone + Quinclorac*	E	E	E	F	U	U	U	U	U	U	U	U	G	U	G	G	E	U	F	P	P
pendimethalin + quinclorac	*Pendimethalin + Quinclorac*	E	-	E	G	U	-	U	U	U	U	U	U	G	-	F	G	G	U	U	P	P
pendimethalin + propanil	*Pendimethalin + Propanil*	E	-	E	E	U	-	U	U	U	E	F		E	-	G[4]	U	G	P[4]	G[4]	P	U
Permit	*Halosulfuron*	U	U	U	U	U	U	E	G	U	G	G	U	F	U	G	F	E	U	U	P	U
Permit Plus	*Halosulfuron + Thifensulfuron*	U	U	U	U	U	U	E	G	U	E	G	F	G	U	G	F	E	G	P	P	P
Stam, SuperWham, RiceShot	*Propanil*	E	E	E	F	U	U	U	G	G	F	P	F	G	U	G	P	G	P	F	F	P
Propanil + Aim	*Propanil + Carfentrazon*	E	E	E	F	U	U	P	U	U	F	F	F	G	U	E	E	E	G	E	G	F
Propanil + Basagran	*Propanil + Bentazon*	E	E	E	U	U	U	G	G	G	G	E	E	G	G	G	U	G	G	G	F	U
Propanil + Permit	*Propanil + Halosulfuron*	E	E	E	F	U	U	E	G	G	G	G	P	G	U	G	G	G	P	G	G	P
Propanil + Strada	*Propanil + Orthosulfamuron*	E	E	E	E	U	U	G	E	G	E	E	G	G	U	E	G	E	F	G	G	G
RebelEx	*Cyhalofop + Penoxulam*	E	U	G	G	U	G	G	E	G	G	G	E	G	U	G	P	E	G	G	F	G

Table 11a. Weed response ratings for rice herbicides.

		Weeds and control																				
Herbicides	***Active Ingredient***	**Barnyardgrass**	**Crabgrass**	**Signalgrass**	**Sprangletop**	**Red rice**	**Johnsongrass**	**Nutsedges**	**Flatsedges**	**Spikerush**	**Ammania (redstem)**	**Dayflower**	**Ducksalad**	**Eclipta**	**Gooseweed**	**Jointvetchs**	**Morningglories**	**Hemp Sesbania**	**Smartweed**	**Water-hyssop**	**Texasweed**	**Alligatorweed**
Regiment	*Bispyrabac Sodium*	E	U	U	U	U	G	P	G	U	F	G	F	F	G	G	F	G	G	G	G	F
RiceBeaux (Propanil + Bolero)	*Propanil + Thiobencarb*	E	E	E	G	U	P	P	G	E	G	G	F	G	F	G	P	G	P	G	G	P
Ricestar HT	*Fenoxaprop-P-Ethyl*	E	P	G	G	U	P	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Strada	*Orthosulfamuron*	U	U	U	U	U	U	G	E	-	E	G	F	G	-	E	F	E	F	G	F	P
Strada PRO	*Orthosulfamuron + Halosulfuron*	U	U	U	U	U	U	E	E	-	E	G	F	G	-	E	F	E	F	G	F	P
Strada XT2	*Orthosulfamuron + Quinclorac*	E	E	E	U	U	U	G	E	-	E	G	F	E	-	E	G	E	F	G	P	F
Storm	*Bentazon + Acifluorfen*	U	U	U	U	U	U	G	G	G	E	E	E	G	G	U	U	E	F	G	U	U

Control symbols: U=Unacceptable <59%, P=Poor 60 – 69%, F=fair 70-79%, G=good 80-89%, E=excellent 90-100%, "-" = data not available. Control expected under optimum conditions.

[1] Annual sedge suppression. [2] With proper water management, refer to label. [3] Weeds must be < 4 inches tall. [4] Controlled only when small (< 2 leaf). [5]Control is based on yellow nutsedge. [6]Seedling only [7]Mid-Season.

Table 11b. Weed response ratings for rice herbicides.

Herbicides		Weeds and control																					
	Active Ingredient	**Barnyardgrass**	**Crabgrass**	**Signalgrass**	**Sprangletop**	**Red rice**	**Johnsongrass**	**Nutsedges**	**Flatsedges**	**Spikerush**	**Ammania (redstem)**	**Dayflower**	**Ducksalad**	**Eclipta**	**Gooseweed**	**Jointvetchs**	**Morningglories**	**Hemp Sesbania**	**Smartweed**	**Water-hyssop**	**Texasweed**	**Alligatorweed**
POSTFLOOD																							
2,4-D	*2,4-D*	U	U	U	U	U	-	U	G	G	E	E	E	E	F	F	E	E	F	E	E	F
Clincher	*Cyhalofop*	G	U	E	E	U	-	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Gambi1	*Halosulfuron + Prosulfuron*	U	-	U	U	U	-	E	E	-	E	G	E	E	-	E	E	E	E	F	G	G
Grasp	*Penoxulam*	G	U	U	U	U	-	F	E	G	F	G	E	E	–	E	U	G	G	G	–	G
GraspXtra	*Penoxulam + Triclopyr*	E	U	U	U	U	-	G	E	G	E	E	E	E	G	E	E	E	E	E	G	E
Loyant	*Florpyrauxifen-Benzyl*	F[4]	-	F[4]	F[4]	U	-	G	G	G	G	G	E	E	-	E	E	E	E	G	U	E
Permit	*Halosulfuron*	U	U	U	U	U	-	E	G	U	U	U	U	U	U	U	U	G	U	U	U	U
Permit Plus	*Halosulfuron + Thifensulfuron*	U	U	U	U	U	U	E	G	U	E	G	F	G	U	G	F	E	G	P	P	P
RebelEx	*Cyhalofop + Penoxulam*	E	F	G	E	U	-	F	E	G	F	E	E	E	G	E	U	E	G	G	F	G
Regiment	*Bispyrabac Sodium*	E	U	U	U	U	-	U	G	U	F	G	F	F	F	G	F	G	G	G	F	G
Strada	*Orthosulfamuron*	U	U	U	U	U	U	G	E	-	E	G	F	F	-	E	F	E	F	G	F	F
Strada PRO	*Orthosulfamuron + Halosulfuron*	U	U	U	U	U	U	E	E	-	E	G	F	F	-	E	F	E	F	G	F	F
CLEARFIELD SYSTEM																							
Preemergence																							
Clearpath	*Imazethapyr + Quinclorac*	E	-	E	G	G	-	E	-	-	G	F	G	G	-	F	G	F	F	F	F	F
Newpath[8]	*Imazethapyr*	G	F	E	G	G	F	E	F	-	G	F	G	F	-	U	G	U	F	F	G	F
Postemergence																							
Beyond	*Imazamox*	G	-	E	F	E	-	G	-	-	G	F	U	F	-	U	G	U	P	F	F	U
Clearpath	*Imazethapyr + Quinclorac*	E	-	E	F	G	-	G	-	-	U	F	U	E	-	G	G	G	F	F	F	P

Table 11b. Weed response ratings for rice herbicides.

Herbicides		Weeds and control																				
	Active Ingredient	**Barnyardgrass**	**Crabgrass**	**Signalgrass**	**Sprangletop**	**Red rice**	**Johnsongrass**	**Nutsedges**	**Flatsedges**	**Spikerush**	**Ammania (redstem)**	**Dayflower**	**Ducksalad**	**Eclipta**	**Gooseweed**	**Jointvetchs**	**Morningglories**	**Hemp Sesbania**	**Smartweed**	**Water-hyssop**	**Texasweed**	**Alligatorweed**
Newpath[8]	*Imazethapyr*	G	F	E	G	G	F	E	F	-	G	F	G	F	-	U	G	U	F	F	G	F
PROVISIA SYSTEM																						
Postemergence																						
Provisia	*Quizalofop P-Ethyl*	E	E	E	E	E	E	U	U	-	U	U	U	U	-	U	U	U	U	U	U	U

Control symbols: U=Unacceptable <59%, P=Poor 60-69%, F=fair 70-79%, G=good 80-89%, E=excellent 90-100%, "-" = data not available. Control expected under optimum conditions.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas

Herbicides	Application Rate/ac	Comments
Preemergence or DELPRE Emergence		
Bolero® 8E	1–2 pt (2.0–4.0 lb a.i. thiobencarb)	PRE or DELPRE, refer to label. Rate not dependent on soil factors (texture, organic matter, etc.); safe on rice as soil-applied herbicide; can be used on water-seeded rice; and residual control.
Command® Up-Stage Caravel	0.7-1.6 pt (0.4-0.6 lb ai clomazone)	Can be applied to preemergence or delayed preemergence; can be applied in split applications with the second application up to 5-leaf rice; provides excellent control of grassy weeds; very economical; rate dependent on soil texture; application technique critical; does not control broadleaf or aquatic weeds; and does not control emerged grasses.
Facet® L Zurax® L	21.0–42.0 fl oz (0.25–0.50 lb a.i. quinclorac)	Can be applied preemergence or delayed preemergence; season-long control of susceptible weeds; water management is not critical; safe on rice; easier mixing compared to Facet® 75DF; narrow-spectrum control; rate dependent on soil texture; and do not apply preemergence to water-seeded rice.
Gambit®	1 - 2 fl oz + MSO (0.031-0.062 lb a.i. halosulfuron + 0.018-0.036 lb a.i. prosulfuron)	Can be applied as a pre-plant burndown with glyphosate or as a preemergence with an herbicide with residual activity on grasses. Provides excellent control of broadleaf weeds and sedges.
League®	3.2–6.4 oz (0.15–0.3 lb a.i. azosulfuron)	PRE or DELPRE, refer to label. Corn, grain sorghum and soybean plant back restricted for 12 months; postemergence control restricted to weeds less than 3 inches; excellent residual control of sedge and broadleaf weeds; and does not control grassy weeds.
Obey™ 2.5ZC	26.0–52.0 oz (0.25-0.5 lb a.i. clomazone + 0.25-0.5 lb a.i. quinclorac)	Can be applied preemergence or delayed preemergence; season-long control of susceptible weeds; water management is not critical; safe on rice; narrow spectrum control; rate dependent on soil texture; and do not apply preemergence to water-seeded rice.
Permit®	0.67–1.34 oz + surfactant (0.031–0.062 lb a.i. halosulfuron)	Excellent control of sedges; safe on rice; does not control grassy weeds; and narrow weed spectrum.
Prowl® H20	1.5–2.0 pt /acre (0.75–1.0 lb a.i. pendimethalin)	Good control of grass weeds; residual control; narrow-spectrum control; short residual control of grass weeds; and water management is critical.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas		
Herbicides	**Application Rate/ac**	**Comments**
RiceOne®	35-50 oz (0.70-1.00 lb a.i. pendimethalin + 0.29-0.42 lb a.i. clomazone)	Can be applied as a delayed preemergence or early postemergence; do not apply as a preemergence treatment immediately after planting; application rates are soil texture dependent (see the label for proper rates); excellent control of barnyardgrass, broadleaf signalgrass, sprangletop, fall panicum and small seeded broadleaf weeds; do not apply to water-seeded rice; water management critical.
Sharpen®	2 oz + COC (0.04 lb a.i. saflufenacil)	Can be applied as a preemergence but not as a postemergence (not labelled) in Texas; Control of many broadleaf weeds and grasses less than 2-3 leaf.
Strada XT[2]®	6.5 –10.0 oz (orthosulfamuron + quinclorac)	Can be applied preemergence or delayed preemergence; excellent control of susceptible grasses and emerged broadleaves; does not control sprangletops; rate dependent upon soil texture; and do not apply preemergence to water-seeded rice or spray directly on exposed rice seed as severe injury may occur.
Postemergence		
Aim® EC	1.6–3.2 fl oz + surfactant (0.025–0.05 lb a.i. carfentrazone-ethyl)	Good control of many broadleaf weeds; low use rates; very economical; Timing of application critical; must be applied to small weeds for efficacy; and no residual control.
Basagran®	1.5–2.0 pt (0.75–1.0 lb a.i. bentazon)	Very safe on rice; excellent control of yellow nutsedge and dayflower; no residual control; and very narrow weed control spectrum when applied alone.
Blazer®	1 pt + surfactant (0.25 lb a.i. acifluorfen)	Excellent control of hemp sesbania; timing of application is not critical; and very narrow weed spectrum.
Clincher® SF	10-15 fl oz + 1 qt COC (0.19–0.28 lb a.i. cyhalofop)	Broad-spectrum grass control; safe on rice; no residual control of weeds; and performance dependent on environmental conditions; and soil moisture is important for effective control.
Command® Up-Stage Caravel	0.7–1.6 pt (0.4–0.6 lb a.i. clomazone)	Can be applied in split applications with the second application up to 5-leaf rice; provides excellent control of grassy weeds; very economical; rate dependent on soil texture; application technique critical; does not control broadleaf and aquatic weeds; and does not control emerged grasses.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas

Herbicides	Application Rate/ac	Comments
Duet®	3.0 – 5.0 qt + 1 qt COC (a.i. propanil + bensulfuron-methyl)	Broad-spectrum weed control; strong on broadleaf aquatic weeds; safe on rice; limited residual control of some weeds; and performance dependent on environmental conditions.
Facet® L Zurax® L	21.0–42.0 fl oz + COC (0.25–0.50 lb a.i. quinclorac)	Season-long control of susceptible weeds; water management not critical; safe on rice; easier mixing compared to Facet® 75DF; and narrow spectrum control.
Gambit®	1 - 2 fl oz + MSO (0.031-0.062 lb a.i. halosulfuron + 0.018-0.036 lb a.i. prosulfuron)	Can be applied as a postemergence; excellent control of broadleaf weeds and sedges; activity on actively growing (1-3 leaf stage) weeds and sedges of 3-6 leaf stage; do not flush or flood within 48-72 hours after application.
Grandstand R®	0.5-0.67 pt + surfactant (0.19-0.25 lb a.i. triclopyr)	Good control of broadleaf weeds; environmental conditions do not have large impact on performance; excellent broad-spectrum control of weeds when applied in combination with Stam M4, Stam 80 EDF or Grasp; water management is critical; delay flooding for 72 hours after application; does not control grasses; may cause injury on young rice; and apply after 2- to 3-leaf stage.
Grasp®	2.0–2.3 fl oz + COC or MSO (0.031–0.036 lb a.i. penoxsulam	Residual control of some weeds and barnyardgrass; broad-spectrum control of broadleaf weeds; and antagonism from Stam on alligatorweed.
GraspXtra®	16.0–18.0 fl oz + COC or MSO 1 qt (a.i. penoxsulam + triclopyr)	Residual control for some weeds and barnyardgrass; broad-spectrum control of broadleaf weeds; water management is critical; and minimum 10 gal/acre spray volume.
League®	3.2–4.0 oz +approved surfactant (0.15–0.19 lb a.i. imazosulfuron	Corn, grain sorghum and soybean plant back restricted for 12 months; postemergence control restricted to weeds less than 3 inches; excellent contact and residual control of sedge, aquatic, and broadleaf weeds; and does not control grass weeds.
Londax®	1.0–1.66 oz + surfactant (0.6–1.0 oz a.i. bensulfuron)	Safe on rice; timing of application is not critical; provides some residual control; narrow spectrum control; water management is critical; and water must cover weeds and remain static in field for a minimum of 5 days.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas

Herbicides	Application Rate/ac	Comments
Loyant™	16 oz + MSO (0.026 lb a.i. rinskor)	Broad-spectrum control of most weeds including grass, broadleaf, sedge and aquatic weeds; excellent control of most broadleaf and sedge weeds and ducksalad; good control of small barnyardgrass, broadleaf signalgrass, junglerice, and Amazon sprangletop no larger than 3-to-5 leaf; no activity on Texasweed; no residual activity on weeds that have yet to emerge; at least 70% of the plant parts should be exposed above water if applied after the permanent flood; crop injury may occur if application is made to plants that are cold, drought or heat stressed; avoid use on freshly cut or leveled ground.
Obey™ 2.5ZC	32.0–52.0 oz (0.3-0.5 lb a.i. clomazone + 0.3-0.5 lb a.i. quinclorac)	Apply up to the 5-leaf rice stage; season-long control of susceptible weeds; water management is not critical; safe on rice; narrow spectrum control; rate dependent on soil texture; and can be applied in sequential application with Command 3ME.
Permit®	0.67–1.34 oz + surfactant (0.031–0.062 lb a.i. halosulfuron)	Excellent control of sedges; safe on rice; does not control grassy weeds; and narrow weed spectrum.
RebelEx®	18.0–20.0 fl oz + COC or MSO (1 qt a.i. penoxsulam + cyhalofop)	Residual control for some weeds and barnyardgrass; broad spectrum control of broadleaf weeds; antagonism from Stam on alligatorweed; moist soil is critical for good activity; water management critical; and minimum 10 gal/acre spray volume.
Regiment®	0.40 – 0.57 oz + either an approved surfactant or 2% UAN (Urea ammonium nitrate solution) (11.25–15.0 gm a.i. bispyribac-sodium)	Broad spectrum control of broadleaf weeds and flatsedges; excellent control of large barnyardgrass; good control of alligatorweed; and no residual control.
RiceBeaux®	3.0–7 qt + surfactant (a.i. propanil + thiobencarb)	Rate not sensitive to soil characteristics (texture, organic matter, etc.); safe on rice as soil-applied herbicide; can be used on water-seeded rice after the 3-leaf stage of rice; residual control of grasses; performance dependent on environmental conditions; and phytotoxic interaction with certain insecticides.
RiceOne®	35-50 oz (0.70-1.00 lb a.i. pendimethalin + 0.29-0.42 lb a.i. clomazone)	Can be applied with another herbicide as an early postemergence to control emerged weeds; application rates are soil texture dependent (see the label for proper rates); excellent control of barnyardgrass, broadleaf signalgrass, sprangletop, fall panicum and small seeded broadleaf weeds; do not apply to water-seeded rice; water management critical.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas

Herbicides	Application Rate/ac	Comments
RicePro®	2.0–4.0 qt + COC (1.0 qt/acre a.i. propanil + quinclorac)	Safe on rice; broad spectrum weed control; performance dependent on environmental conditions; and phytotoxic interaction with certain insecticides.
Ricestar HT®	13.0–17.0 fl oz (0.94–1.23 lb a.i. fenoxaprop-P)	Safe on rice; excellent control of grassy weeds; does not control broadleaf, aquatic weeds, or sedges; and multi-tillered grass control, good to poor.
Propanil (Stam M4, 80 EDF, RiceShot and SuperWham)	2.0–4.0 qt or 3.75–5.0 lb (2.0–4.0 lb a.i. propanil)	Safe on rice; broad-spectrum weed control; used in combination with many other herbicides to increase spectrum of weed control; no residual control; performance dependent on environmental conditions; phytotoxic interaction with certain insecticides; and always use surfactant or COC with Stam 80 EDF or SuperWham.
Propanil + Aim® EC	2.0–4.0 qt + 1.6–3.2 fl oz (2.0–4.0 lb + 0.025–0.05 lb a.i. propanil + carfentrazone)	Broad-spectrum weed control; no residual control; and most effective on small weeds.
Propanil + Basagran®	2.0–4.0 qt + 1.5–2.0 pt (2.0–4.0 lb a.i. propanil + 0.75–1.0 lb a.i. bentazon)	Safe on rice; broad-spectrum weed control; and no residual control.
Propanil + Bolero® 8E	2.0–4.0 qt + 1–2 pt (2.0–4.0 a.i. propanil + 2.0–4.0 lb a.i. + thiobencarb)	Rate not dependent on soil factors (texture, organic matter, etc.); safe on rice as soil-applied herbicide; can be used on water-seeded rice; and residual control.
Propanil + Grandstand R®	1.0–4.0 qt + 0.5–0.67 pt (1.0–4.0 lb a.i. propanil+ 0.19–0.25 lb a.i. triclopyr)	Broad-spectrum weed control; water management critical; delay flooding for 72 hours after application; and may cause injury on young rice.
Propanil + Permit®	2.0–4.0 qt + 0.67–1.34 oz (2.0–4.0 lb a.i. propanil + 0.031–0.062 lb a.i. halosulfuron)	Broad-spectrum weed control; safe on rice; and no residual control
Storm®	1.5 pt + surfactant (0.5 lb a.i. bentazon + 0.25 lb a.i. acifluorfen)	Safe on rice; no residual control; and does not control grassy weeds.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas

Herbicides	Application Rate/ac	Comments
Strada®	1.7–2.1 oz + surfactant (0.053–0.065 lb a.i. orthosulfamuron)	Excellent control of sedges; good control of selected broadleaves; safe on rice; good tank mix partner in the CLEARFIELD® System; and does not control grass weeds.
Strada PRO®	2.08 – 2.5 oz + surfactant (0.055 - 0.066 lb a.i. orthosulfamuron + 0.0155 - 0.0186 lb a.i. halosulfuron)	Excellent control of sedges; good control of select broadleaves; safe on rice; good tank mix partner in the CLEARFIELD® System; and does not control grass weeds
Strada XT[2]®	6.5 –10.0 oz product (orthosulfamuron + quinclorac)	Excellent control of susceptible grasses and emerged broadleaves; and does not control sprangletop.
Post flood		
2,4-D Amine 4E	1.5–2.5 pt + surfactant (0.75–1.25 a.i. 2,4-dichlorophenoxy acetic acid)	Very economical; good control of broadleaf weeds; timing of application critical; apply between tillering and panicle initiation; and no residual control.
Clincher® SF	13.5–15.0 fl oz + COC or MSO 1 qt (0.25–0.28 lb a.i. cyhalofop)	Safe on rice; safe on adjacent broadleaf crops (soybean and cotton); good control of annual grassy weeds and knotgrass; and does not control broadleaf weeds or sedges.
Gambit®	1 - 2 fl oz + MSO (0.031-0.062 lb a.i. halosulfuron + 0.018-0.036 lb a.i. prosulfuron)	Can be applied as postflood; control of broadleaf weeds and sedges; weeds should be 70-80% exposed above the water; hold flood water for 14 days after application; do not apply within 48 days of harvest
Grasp®	2.3–2.8 fl oz product + COC or MSO 1 qt (0.036–0.044 lb a.i. penoxsulam)	Controls large barnyardgrass, many broadleaf weeds and flat sedge; excellent control of aquatic weeds; and does not control broadleaf signalgrass, sprangletop or fall panicum.
GraspXtra®	20-22 fl oz + COC or MSO 1 qt (a.i. 0.039-0.043 lb a.i. penoxsulam + 0.234-0.258 lb acid equivalent (a.e.) triclopyr)	Residual control for some weeds and barnyardgrass; broad spectrum control of broadleaf weeds, flat- sedges and barnyardgrass; excellent control of alligatorweed; minimum 10 gal/acre spray volume; and do not apply after rice reaches 0.5” internode length.
Permit®	0.67-1.34 oz + surfactant (0.031–0.062 lb a.i. halosulfuron)	Excellent control of sedges; safe on rice; does not control grassy weeds; and narrow weed spectrum.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas		
Herbicides	**Application Rate/ac**	**Comments**
Permit® - Seed head suppressive	1.0–1.34 oz + surfactant (0.046–0.062 lb a.i. halosulfuron)	Seed head suppression of hemp sesbania and northern jointvetch; safe on rice; do not apply within 48 days of harvest; and narrow weed spectrum.
RebelEx®	18.0–20.0 fl oz + COC or MSO 1 qt (0.035-0.039 lb a.i. penoxsulam + 0.25-0.278 lb a.i. cyhalofop)	Residual control for some weeds; broad- spectrum control of broadleaf weeds; antagonism from Stam on alligatorweed; water management critical; minimum 10 gal/acre spray volume; and do not apply within 60 days of harvest.
Regiment®	0.40–0.57 oz + either an approved surfactant and 2% UAN or an approved surfactant that contains UAN (11.25–15.0 gm a.i. bispyribac-sodium)	Broad-spectrum control of broadleaf weeds and aquatic weeds; excellent control of large barnyardgrass; and no residual control.
Strada®	2.1 oz + surfactant (0.065 lb a.i. orthosulfamuron)	Excellent control of flatsedges; good control of selected broadleaves; weeds must be exposed to ensure adequate coverage; safe on rice; good tank mix partner in the CLEARFIELD® System; and does not control grassy weeds.
Strada PRO®	2.08 – 2.5 oz + surfactant (0.055–0.066 lb a.i. orthosulfamuron + 0.0155 - 00.186 lb a.i. halosulfuron)	Excellent control of sedges; good control of selected broadleaves; safe on rice; good tank mix partner in the CLEARFIELD® System; and does not control grass weeds.
CLEARFIELD® System		
Beyond®	5.0 oz + COC (0.04 lb a.i. imazamox)	Controls weedy (red) rice escapes in CLEARFIELD; limited carryover; restricted to imidazolinone-tolerant rice varieties or hybrids possessing the second-generation herbicide resistance trait; cannot be tank-mixed with other herbicides; can be applied late postemergence or postflood after two applications of Newpath; timing is critical; two-thirds of the weedy rice plant must be exposed for effective postflood applications.
Clearpath®	0.5–0.72 lb + COC (a.i. imazethapyr + quinclorac)	Excellent control of weedy (red) rice, grassy weeds and nutsedge; provides additional broadleaf control to the CLEARFIELD system; can be applied preplant, preemergence, or postemergence; residual control; application timing and water management is critical; CLEARFIELD varieties must be grown; Clearpath must be preceded or followed by Newpath; restricted to imidazolinone-tolerant rice varieties or hybrids possessing the second-generation herbicide resistance trait.

Table 11c. Herbicides, application rates and use recommendations on weed control in Texas		
Herbicides	**Application Rate/ac**	**Comments**
Newpath®	4.0–6.0 oz + COC (a minimum of 12.8 oz for postemergence applications, 0.0625 a.i. imazethapyr)	Excellent control of weedy (red) rice, grass weeds and nutsedge; residual control; application timing and water management are critical; seasonal application not to exceed 12 oz/acre; chemical rate, water volume and adjuvant rates are critical; CLEARFIELD varieties must be grown; two applications are required (only soybeans can be planted after 12 oz product/acre); restricted to imidazolinone-tolerant rice varieties or hybrids possessing the second-generation resistance trait.
PROVISIA® System		
Provisia®	13-18 oz + COC (0.09-0.12 lb a.i. quizalofop)	Apply only to Provisia® rice varieties; excellent control of red rice, weedy rice/volunteer rice types (conventional, Clearfield® or hybrid volunteer rice), and annual and perennial grass weeds; two sequential applications can be made from 1-leaf stage up to panicle initiation of rice; 2nd application must be made prior to panicle initiation of rice for complete control of red and volunteer rice due to extended emergence; separate sequential applications by at least 10 days; do not apply more than a total of 31 ounces per acre (0.21 lb a.i./ac) per year; crop injury (yellow foliage) may occur; avoid spray overlap; refer to the label for approved mixture applications.

Herbicide Resistance Management

Herbicide-resistant weeds pose a challenge to sustainable weed management in Texas rice production. In a rice consultant/grower survey, about 46, 27 and 15% of the respondents expressed high, moderate, and low levels of concern, respectively, towards herbicide-resistant weeds in their operations. Some key rice herbicides have already been lost, and we cannot afford to lose any more herbicides to resistance.

Field surveys were conducted prior to harvest in Texas rice during the 2015 and 2016 cropping seasons to document the distribution of problematic weed species and evaluate the status of herbicide resistance. The results revealed that barnyardgrass, sprangletops (particularly Nealley's sprangletop), hemp sesbania and weedy rice are among the most important weeds across the Texas rice belt. Preliminary results of our herbicide resistance evaluations revealed that resistance to Propanil®, Facet®, and/or Newpath® are common in the barnyardgrass populations across the region. Several weedy rice populations have also shown resistance to Newpath®. Multiple herbicide resistance is particularly an emerging issue. Herbicide resistance will remain a significant concern unless diverse management tactics are implemented. An effective resistance management strategy for rice will include the use of a strong pre-emergence herbicide such as clomazone (Command®), followed by an early-post and a post-flood application with different herbicide modes of action to clean up any escapes. Effective flood management will help reduce weed seedling emergence and seed production. Best herbicide resistance management practices also involve applications of herbicides using the right equipment (proper calibration, selection of nozzles, etc.) at the right timing (small weed growth stage) and rate (full labeled rates) to achieve the maximum efficacy. Growers should routinely scout for weed issues and pay close attention to weed escapes present during the late season. It is likely that such late-season weed escapes are resistant and removing them prior to buildup in numbers will be critical to minimizing weed seed addition to the seedbank.

Herbicide-resistant weeds develop due to repeated use of herbicides that affect the same biochemical site of action (SOA) in plants. Effective resistance management requires diversified use of herbicides that affect different SOAs and non-chemical control tools in a program. Tables 10d-f provide information on the SOA of various herbicides and premix products used in rice to assist with proper herbicide selection for management of resistant weeds.

Table 11d. Rice herbicides, active ingredients, sites of action, and WSSA group.

WSSA Group	Site of Action[1]	Active Ingredient	Trade Name[2]
1	ACCase inhibitors	cyhalofop	Clincher
		fenoxaprop	RiceStar HT
		quizalofop	Provisia
2	ALS inhibitors	bispyribac	Regiment
		bensulfuron- methyl	Londax
		halosulfuron	Permit, Halomax
		imazethapyr	Newpath
		imazamox	Beyond
		imazosulfuron	League
		orthosulfamuron	Strada
		penoxsulam	Grasp
3	Microtubule inhibitors	pendimethalin	Prowl
4	Synthetic auxins	florpyauxifen-benzyl	Loyant
		quinclorac	Facet
		triclopyr	Grandstand
		2,4-D amine	2,4-D
6	Photosystem II-inhibitors	bentazon	Basagran
7	Photosystem II-inhibitors	propanil	Propanil, Riceshot, SuperWham
8	Lipid synthesis inhibitors	thiobencarb	Bolero
13	Diterpene synthesis inhibitors	clomazone	Command
14	Protoporphyrinogen oxidase inhibitors	acifluorfen	Ultra Blazer
		saflufenacil	Sharpen
		carfentrazone	Aim
27	HPPD inhibitors	benzobicyclon	Rogue

[1] The site of action is the biological location on the target plant that is affected by the herbicide. The site of action group is developed by the Weed Science Society of America (WSSA).
[2] Label and SDS (Safety Data Sheet) can be downloaded from www.cdms.net (or) www.greenbook.net

Table 11e. Premix herbicide products with different sites of action used in rice.

Premix Product	Active Ingredients	WSSA Groups[1]
Duet	propanil + bensulfuron	**7+2**
Gambit	halosulfuron +	**2+2**
Grasp	penoxsulam + triclopyr	**2+4**
Obey	quinclorac + clomazone	**4+13**
Permit	halosulfuron +	**2+2**
RebelEX	penoxsulam + cyhalofop	**2+1**
RiceBeaux	propanil + thiobencarb	**7+8**
RiceOne	pendimethalin +	**3+13**
Rogue	benzobicyclon +	**27+2**
Strada XT	orthosulfamuron +	**2+4**
Storm	bentazon + acifluorfen	**6+14**

[1]Site of action group is developed by the Weed Science Society of America (WSSA).

Table 11f. WSSA site of action groups and resistant weeds in rice in the US[1].

WSSAGroup[2]	Resistant Weeds
1	Barnyardgrass, Amazon sprangletop, late watergrass
2	Barnyardgrass, junglerice, weedy rice, rice flatsedge, yellow nutsedge, small flower umbrella sedge, California arrowhead, redstem, ricefield bulrush
3	None reported
4	Barnyardgrass, smooth crabgrass
6, 7	Barnyardgrass, junglerice, smallflower umbrella sedge, ricefield bulrush
8	Barnyardgrass, late watergrass, early watergrass
13	Barnyardgrass
14	None reported
27	None reported

[1] Based on the reports of herbicide-resistant weeds in rice documented at www.weedsscience.org

Disease Management

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Plant diseases are a serious limiting factor in the production of rice in Texas. The Texas Gulf Coast provides a warm, humid climate favorable for the development and spread of many diseases. Fungi are the major disease-causing organism affecting Texas rice. These include seed rot and seedling diseases, sheath blight, blast, narrow brown leaf spot (also called Cercospora leaf spot), sheath rot, stem rot, brown spot, black sheath rot, false smut, and kernel smut. Seedling diseases, sheath blight, blast, narrow brown leaf spot, and kernel smut are among the most important diseases affecting rice production in Texas each year. Kernel smut, once a minor disease due to its sporadic occurrence, has become a major disease in recent years. Bacterial panicle blight, caused by *Burkholderia glumae* and *B. gladioli*, has also caused significant damage to rice production in some years. Straighthead, a physiological disorder caused by high arsenic levels in the soil and other unknown causes, occasionally results in a significant reduction in the yield and quality of rice. Texas and other U.S. rice-producing states currently do not have any serious viral or nematode diseases.

Over the past decade, many changes in rice production practices designed to achieve maximum yields have also created conditions favorable for the development of diseases. Some of these practices include increased nitrogen fertilization, increased acreage planted with susceptible varieties, shortened rotations, increased acreage of rotation with soybean, and high seeding rates.

Several options for the management of rice diseases are available. However, employing single disease management options are frequently not very effective or sustainable. Instead, rice producers should try to manage disease losses through an integrated use of resistant varieties, sound cultural practices, and chemical controls.

Seedling Diseases

Seed rot and seedling blight are caused by various seed-borne and soil-borne fungi. Seedling blight is also called damping-off. This disease complex can cause irregular, thin stands and weakened plants (Fig. 12a). Cool, wet soil and other conditions that delay seedling emergence favor the development of seed rot and seedling diseases. Severe seed rot and seedling diseases may result in the need to replant.



Fig. 12a. A field with seedling disease.

The organisms that cause seed rot and seedling blight include *Achlya* spp., *Cochliobolus miyabeanus*, *Fusarium*

spp., *Pythium* spp., *Rhizoctonia solani* AG-11, *R. solani* AG-4, *Sclerotium rolfsii,* and other pathogenic fungi. Recent surveys show *R. solani* AG-11 is the most prevalent pathogen, followed by *Fusarium* spp., *Sclerotium rolfsii,* and *R. solani* AG-4 in dry seeded rice (Gaire et al. 2020). *Marasmius graminum*, a new fungal pathogen that survives in soil or on seeds can also cause seedling blight (Gaire et al. 2021). These fungi infect germinating seeds or young seedlings, resulting in seed rot (Fig. 12b), root damage (Fig. 12c), and slow growth or even seedling death (Fig.12d). Low temperatures slow the germination and growth of rice seedlings, but do not affect the infection by these pathogens. Therefore, damage by these fungi is more severe in rice planted in late February to mid-March when temperatures are typically low.



Fig. 12b. Seed rot (photo courtesy of R. K. Webster.)



Fig. 12c. Healthy (left) and diseased (right) roots.

Seed treatments with fungicides have been shown to significantly increase stand density by 20% in both drill and water-seeded rice, especially in early plantings. Fungicides should not be applied to sprouted, water-seeded rice since the chemicals can be easily washed off and contaminate water. Fungicides can be applied to soaked seeds using specialized equipment. Proper fungicide seed treatments may avoid the need to replant. In addition to fungicide seed treatments, other practices that aid in obtaining a healthy and uniform stand include:



Fig. 12d. Healthy (left) and dead (right) seedlings.

- Plant in a well-prepared, uniform seedbed
- Avoid planting too early
- Plant shallow when planting rice early
- Use healthy seeds with high germination and good vigor
- Treat seeds with plant growth regulators such as Gibberellic Acid (GA) (see the Seed Treatments chapter in this bulletin for more details)

The following fungicides (Table 12a) are registered for use on rice seed. CruiserMaxx® Rice and NipsIt® SUITE Rice System are two recently registered seed treatments, each of which

Table 12a. Fungicides registered for use on rice seed.

Common name	Trade name	Rate/100 lb seed
Azoxystrobin	Dynasty®	0.15-1.5 fl oz
Carboxin + Thiram	Vitavax® CT Vitavax® M	9-12 fl oz 9-12 fl oz
Fludioxonil	Maxim® 4FS Spirato® 480 FS	0.02-0.08 fl oz 0.02-0.08 fl oz
Mancozeb	Dithane® DF Dithane® F 45 Dithane® M 45 Manzate® Flowable Manzate® Pro-Stick	2.1-4.3 oz 3.2-6.4 fl oz 2-4 oz 3.4-6.7 fl oz 2-4 oz
Mefenoxam	Apron XL® LS Apron XL®	0.0425-0.085 fl oz 0.0425-0.085 fl oz
Mefenoxam + Fludioxonil + Azoxystrobin + Thiamethoxam*	CruiserMaxx® Rice containing: Apron XL® Maxim® 4FS Dynasty® Crusier 5FS®	7.0 fl oz containing: 0.141 oz (a.i.) 0.022 oz (a.i.) 0.111 oz (a.i.) 2.222 oz (a.i.)
Fludioxonil + Metalaxyl + Clothianidin*	NipsIt® SUITE Rice System containing: Spirato® 480 FS Sebring® 318 FS NipsIt INSIDE	0.08 fl oz 0.4 fl oz 1.92 fl oz
Metalaxyl**	Dyna-Shield® Sebring® 318 FS	0.75 fl oz 0.75-1.50 fl oz
Sedaxane***	Vibrance	0.035 - 0.353 oz (a.i.)

*Thiamethoxam and clothianidin are insecticides. See the Insect Management chapter for more details.
**Effective for controlling *Pythium* damping-off. Use in combination with another material to broaden spectrum of control.
***Sedaxane may be combined with seed treatment products containing mefenoxam, fludioxonil, and/or azoxystrobin.

contains two or three fungicides and one insecticide targeting a broad spectrum of early-season diseases and selected harmful insect pests. The trade names listed in Table 12a are for informational purposes only and do not constitute an endorsement of the product over other products containing the same active ingredients. Follow the label instructions carefully to avoid problems and obtain maximum efficacy.

Sheath Blight

Sheath blight, caused by the fungus *Rhizoctonia solani* AG1-1A, is the most important rice disease in Texas and probably the second most important rice disease worldwide. The disease is prevalent in Texas rice fields. Under favorable conditions for disease development, sheath blight can cause up to 50% grain yield loss without proper intervention. The occurrence of this disease results in reduced grain yield and quality and increased main crop lodging. Sheath blight in the main crop directly reduces the ratoon crop plant population, causing additional yield losses.

Initial symptoms on sheaths are circular, oval, or ellipsoid, and greenish-gray lesions that start to develop a little above the waterline. The lesions enlarge and coalesce, forming bigger lesions with irregular outlines and grayish-white centers surrounded by dark brown borders (Fig. 12e). As lesions coalesce on the sheaths, entire leaves eventually die. Lesions on the leaf blades are more irregular with dark green, brown, or yellow-orange margins. The lesions can develop extensively and coalesce on partial or whole leaf blades, producing a rattlesnake skin pattern (Fig. 12f). Sclerotia, the survival structures of the fungus, form on the surfaces of sheaths and leaf blades. The sclerotia are white when first formed, and then turn brown or dark brown. Diseased plants exhibit reduced grain filling, especially in the lower portion of the panicles. Yield losses also are associated with increased lodging and reduced ratoon crop production.

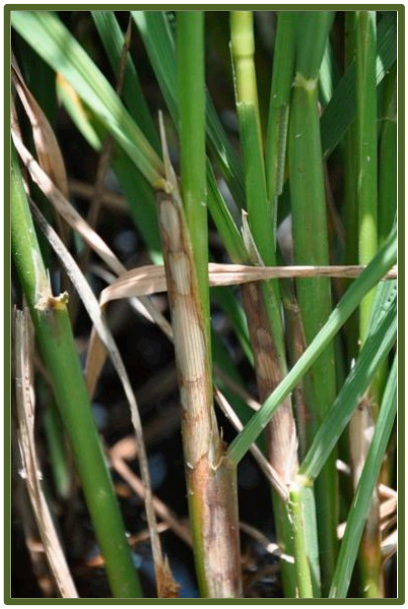


Fig. 12e. Sheath blight lesions on sheath.



Fig. 12f. Sheath blight lesions on leaf.

The increased use of sheath blight-susceptible semidwarf varieties, along with the high nitrogen fertilization required to maximize yield potential, has resulted in greater losses from sheath blight. Also, the trend towards shorter crop rotations and rice grown in rotation with soybeans has made the disease more troublesome. The same fungus infects soybeans and causes aerial blight, which allows the fungus to increase in fields used to grow soybeans. None of the current leading high-yielding rice varieties have acceptable levels of resistance to sheath blight. As a result, rice producers have increased their reliance on fungicides to manage sheath blight.

Cultural Control - An integrated management approach is needed to reduce yield losses from

sheath blight. Some practices may be economical only where sheath blight is a persistent, significant problem. Others are recommended in all situations as sound management practices that will help prevent the buildup of sheath blight inoculum or limit its effects where the problem exists. Some recommended cultural practices include the following:

- Avoid excessive seeding rates, which result in a dense canopy that creates a moist microclimate favorable to disease development
- Avoid excessive rates of nitrogen fertilization, which increases the severity of the disease
- Where possible, increase the interval between rice crops to no more than 1 year of rice in every 3 years. Pasture-pasture-rice, soybean-soybean-rice and rice-soybean-rice rotations have an average incidence of sheath blight of 0.4, 2.7 and 5.4%, respectively, at panicle differentiation (PD). In addition, more sheath blight inoculum tends to be produced in drilled soybeans than in row-planted soybeans
- Control grassy weeds that serve as hosts of the sheath blight fungus. Barnyardgrass, crabgrass, and broadleaf signalgrass are among the most common weed hosts of the pathogen

Variety Selection - Rice varieties differ in susceptibility to sheath blight (Table 12b), with most medium grain and hybrid varieties being less susceptible or moderately resistant (Shi. et al. 2021). Taller varieties tend to sustain less loss than semidwarf varieties. Selecting a variety that is resistant or less susceptible to sheath blight is key to reducing loss caused by the disease.

Table 12b. Disease reaction of rice varieties commercially grown in Texas from 2017-2021.

Variety	Sheath blight	Blast	Kernel smut	Cercospora	Bacterial Panicle blight	Brown spot	Straighthead
Antonio	VS	MR	S	S	S	MR	VS
Cheniere	S	MS*		S	MS*		MR*
CL111	VS	MS	S	S	VS	MR	MS
CL151	S	VS*	S	S	S	MS	VS
CL153	VS	MS*	S*	S			
CL163	VS	VS*	MS*	R	MS*		MS*
CL XL729	MS	R	MS	R	MR	MS	MR
CL XL745	MS	MR	MS	R	MR	MS	-
DG263L	S			R	MR		
Diamond	S	S*		MR	MS*		MS
Dixiebelle	VS	S	VS	MS		R	MR

Table 12b. Disease reaction of rice varieties commercially grown in Texas from 2017-2021.

Variety	Sheath blight	Blast	Kernel smut	Cercospora	Bacterial Panicle blight	Brown spot	Straighthead
CL Gemini 214	MS			MR			
Jewel	S	R		R	S		R
Jupiter	MS	MS	MS	R	MR	MS	S
Mermentau	VS	S*		MR	MS*		S
Presidio	VS	MR	S	S	MS	MR	MR
PVL01	S	VS*	S	MR	S*		
PVL02	VS	MS*	S	S	S*		
PVL03	S	MR*		S	MR*		MR*
RT7321	MR			R			
RT7321FP	MR	R			MR		R
RT7521FP	MS	R			MR		R
Trinity	VS	S	S	MR	MS	MR	
XL723	MS	MR	MS	R	MR	MS	MR
XL753	MR	R		R		MS	
XL760	MS	R*	MS	R	MR	MS	

VR = very resistance; R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; VS = very susceptible. Varieties rated S or VS may show extensive disease under favorable conditions. Varieties rated R or MR show significantly less damage under similar conditions.
* Data on disease reaction for an additional 32 lower acreage varieties based on ratings made in Arkansas and/or Louisiana, can be obtained by contacting Dr. Zhou at xzhou@aesrg.tamu.edu.

Chemical Control - Several fungicides are available for the effective control of sheath blight (Table 12c, also see Uppala and Zhou 2018). In many situations, foliar fungicides may be economically justified for reducing losses from sheath blight if any of the following apply.

- Disease pressure is sufficiently high
- Susceptible varieties of rice are grown
- The crop will be ratooned
- The crop has a high yield potential in the absence of sheath blight
- Environmental conditions are favorable for the disease to spread to the upper leaves of the rice plant

Table 12c. Fungicides and relative efficacy for control of foliar diseases in rice.

Material	Active ingredient	Rate/ac and timing[1]	Sheath blight	Blast	Kernel smut	Cercospora
Aframe ®	Azoxystrobin	9.0-15.5 @ (PD+5 days) to 50% heading	Excellent	Good	Poor	Fair
Amistar Top® SC[2]	Azoxystrobin + difenoconazole	10.0-15.0 fl oz @ (PD+5 days) to 90% panicles emergence	Good	Good	Excellent	Good
Artisan ®	Flutolanil + propiconazole	20-40 fl oz @ (PD+7 days) to heading	Good	-	Good	Good
Bumper ® 41.8 EC	Propiconazole	6.0-10.0 fl oz @ PD to late boot	Fair	-[3]	Good	Good
Elegia® 3.8 F	Flutolanil	16-32 fl oz	Good	-	-	-
Equation® 2.08 SC	Azoxystrobin	9.0-15.5 fl oz @ (PD+5 days) to 50% heading	Excellent	Good	Poor	Fair
Flint Extra ®	Trifloxystrobin	3.1-4.7 fl oz @ PD to 90% panicles emergence	Good	Excellent	Poor	Poor
Gem® 500 SC	Trifloxystrobin	3.8-4.7 fl oz @ (PD+5 days) to 50% heading	Good	Excellent	Good	Fair
Moncut® 70 DF	Benzamide	0.5-0.71 lb @ PD and 10-14 days later or 0.5-1.0 lb @ (PD+10 days) to heading	Good	-	-	-
Propimax® 3.6 EC	Propiconazole	6.0-10.0 fl oz @ PD to late boot				
Quadris® 2.08 SC[4]	Azoxystrobin	9.0-15.5 fl oz @ (PD+5 days) to 50% heading	Excellent	Good	Poor	Fair
Quilt® 200 SC	Azoxystrobin + propiconazole	14.0-34.5 fl oz @ (PD+5 days) to late boot	Good	Good	Good	Good
QuiltXcel® 2.2 SE	Azoxystrobin + propiconazole	14.0-27.0 fl oz	Good	Good	Good	Good
Sercadis® 2.47 SC	Fluxapyroxad	4.5-6.8 fl oz @ PD to late boot	Good	-	-	-[5]
Stratego® 250 EC	Trifloxystrobin + propiconazole	14.0-19.0 fl oz @ (PD+5 days) to late boot	Good	Excellent	Good	Good
Tilt® 3.6 EC	Propiconazole	6.0-10.0 fl oz @ PD to late boot	Fair to Good	-	Good	Good

[1]See product label for more details on application rates and timing.
[2] Labelled for use on both main and ratoon crops.
[3]'-' = Not labelled for use against this disease.
[4]Show some efficacy on stem rot by an application made at 12.5-15.5 fl oz/ac at PD to mid boot.
[5]Show excellent efficacy on Cercospora.

It is difficult to estimate the potential severity of sheath blight to determine the economic feasibility of applying a fungicide. However, given the high costs of fungicide spray programs, the need to reduce production costs, and the rapid rate of development during favorable environmental conditions. an assessment should be made as to the severity of the sheath blight infestation shortly after initiation of the panicle differentiation (PD) growth stage (Fig. 12g).

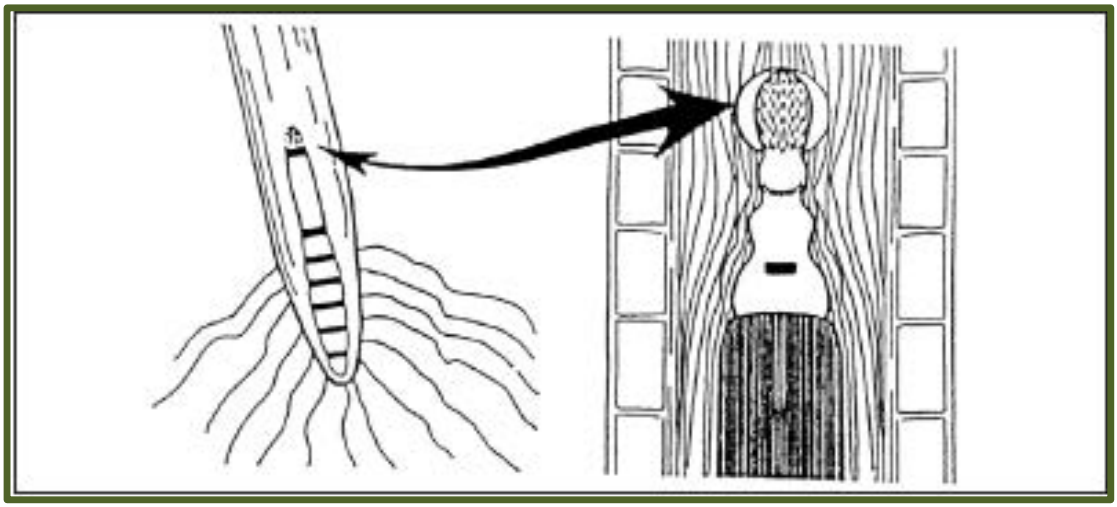


Fig. 12g. Panicle differentiation (PD).

Monitoring for Sheath Blight - Begin scouting for evidence of sheath blight during PD by walking across the field in a zigzag pattern (Fig. 12h), periodically observing rice above the water line for evidence of early sheath blight lesions. A helpful sampling tool can be made from a 3/4-inch PVC pipe fashioned into the shape of a "T," with a 4-foot handle connected by a "T" joint to two 14-inch lateral tubes. The device is used to push open the rice canopy and is a back-saver. If no sheath blight is found, wait a week, and monitor again. If some sheath blight is found, more detailed monitoring is necessary to accurately estimate the amount of sheath blight present. It may be necessary to precisely monitor a field with a recent history of severe sheath blight that is on a short crop rotation (more than one rice crop in a 3-year interval). Under high disease-conducive conditions, all varieties benefit from a fungicide for sheath blight control.

To monitor more precisely, divide large fields into 45-to-50-acre sections and inspect each section separately (Fig. 12h). Walk the field sections in a "U" pattern, randomly stopping to check for the presence of sheath blight. Record stopping points as positive for sheath blight even if only one small sheath blight lesion is found on a single plant. The stopping point is considered negative if no sheath blight symptom is found. The total number of stops should be at least equal to the number of sections in the area scouted (i.e., 45 acres = 45 or more stops). Finally, divide the number of positive stops by the total number of stops and multiply by 100. This will give the percentage of positive sheath blight stopping points.

The thresholds for economical fungicide application are based on the amount of sheath blight present at PD and the variety planted (Table 12d). With very susceptible and susceptible varieties, 35% positive stops indicate that a fungicide is necessary. A moderately susceptible variety requires 50% positive stops to justify a fungicide treatment.

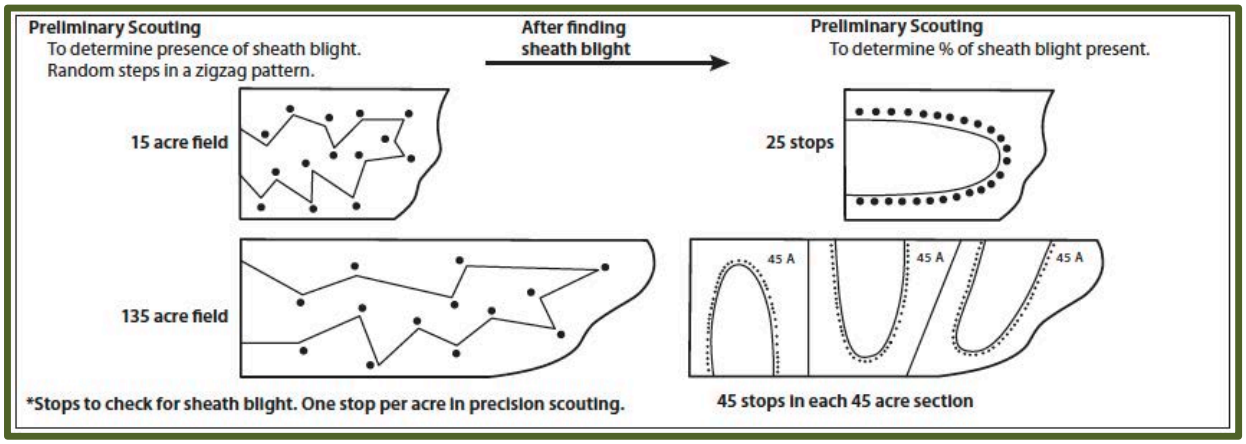


Fig. 12h. Suggested scouting procedure for sheath blight.

The thresholds are based on main crop production and do not consider the possibility of ratoon cropping the field. It is well documented that when sheath blight is controlled by fungicides in the main crop, a significant increase in yield also can occur in the ratoon crop. Therefore, if a ratoon crop is planned, the thresholds might be reduced to 25% positive stops for very susceptible varieties and 30% positive stops for moderately susceptible varieties.

Table 12d. Threshold guidelines suggested for economical fungicide application for management of sheath blight.

Sheath blight susceptibility*	Positive stops	Infected tillers
Very susceptible varieties: Antonio, Catahoula, CL111, CL161, Colorado, Mermentau, Presidio, etc.	35%	5%
Moderately susceptible to moderately resistant varieties: Jasmine 85, Wells, Rondo, medium grain varieties and hybrid varieties	50%	10%

* See Table 12b for sheath blight susceptibility ratings.

Sheath blight should be monitored periodically during the development of the rice crop through heading. The thresholds are estimates based on information and conditions occurring at the time of evaluation, preferably at PD. If favorable weather conditions develop later and persist, sheath blight can develop rapidly and make the original threshold determination obsolete.

In the past, two fungicide applications were necessary to control sheath blight, but with the advent of more effective fungicides and economic restraints, a single application is generally used. Fungicides are normally applied between 7 days after PD and 50 to 70% heading. Earlier applications tend to not provide season-long control, while late applications can allow sheath blight to cause significant damage early in the season. Fungicides must be applied by the heading growth stage since control is drastically reduced with as little as a 5-day delay. Follow the manufacturer's instructions on the label for fungicide applications.

Several other factors to consider in deciding whether to use a fungicide include plant density, prevailing weather, and ratoon cropping. The denser the canopy, the more favorable the conditions for sheath blight to develop.

Rice Blast

Rice blast, caused by the fungus *Magnaporthe oryzae* (syn: *Pyricularia grisea*), can cause severe losses to susceptible varieties when environmental conditions, such as warm and moist weather, favor disease development. The blast fungus causes symptoms of leaf spots and lesions on young plants from the seedling to tillering stages, and panicle blast or rotten neck symptoms after heading. Leaf lesions are football- or spindle-shaped and elongated with brown to purple-brown borders and grayish centers (Fig. 12i). Leaves and even whole plants are often killed when the disease is severe, especially in upland or non-flooded situations.



Fig. 12i. Leaf blast.

The rotten neck phase of the disease is commonly observed 5 to 10 days after head emergence. With rotten neck, a brownish lesion at the node at the base of the panicle (Fig. 12j) often prevents the grain from filling or weakens the neck of the panicle so that filled panicles easily break off before harvest.

Growing varieties that are resistant to blast is the most effective method for management. Some varieties, especially hybrids, are resistant to blast (Table 12b). However, the rice blast fungus is a highly variable population in pathogenicity and there are many pathogenic races. In recent years, the races IC-17 and IB-49 have been the most prevalent in Texas. The adoption of varieties with resistance to these races of the blast fungus has greatly reduced losses. In the past years, the occurrence of the disease had been rare in Texas. However, since 2012, outbreaks of rice blast have occurred each year in localized areas.



Fig. 12j. Neck blast.

Chemical control of blast is usually not recommended when resistant or moderately resistant varieties (Table 12b) are planted. When moderately susceptible or susceptible varieties are grown in the areas where blast has historically occurred, preventive applications of triazole and/or strobilurin (Amistar Top®, Equation® Gem®, Quadris®, Stratego®, Quilt®, or QuitXcel®) may be necessary (Table 12c).

The rotten neck phase of blast can occur without leaf blast symptoms because the spores of the pathogen can become air-borne and be

blown into the field from a distant source. If leaf blast lesions are in the field, the potential outbreak for the rotten neck phase of blast is greatly increased.

The application of fungicides at the late booting stage is most effective when there are several leaf blast lesions. For optimum blast control, apply Amistar Top®, Equation® Gem®, Quadris®, Stratego®, Quilt® or QuitXcel® (Table 12c) at the late boot stage to reduce sporulation on leaf lesions and to protect the collar of the flag leaf. Apply again about 5 to 7 days later when 50% of the main tillers have 70 to 90% of the panicle length emerged.

The application at the heading stage is more important for protecting panicles from spore showers. The heading growth stage is critical for blast control since a delay of as little as 5 days can greatly reduce fungicide efficacy. Blast is favored by excessive nitrogen fertility, thick stands, light sandy soils, and inadequate flooding.

Narrow Brown Leaf Spot

Narrow brown leaf spot (also called Cercospora leaf spot) is caused by the fungus *Cercospora janseana.* The severity of the disease has increased over the years, and it is now considered one of the most important rice diseases in Texas. The disease tends to be more severe at late plantings and in the ratoon crop, causing premature ripening and reducing yield and milling quality. Generally, the disease is more severe in the ratoon crop than in the main crop.

The fungus attacks the leaves (Fig. 12k), sheaths (Fig. 12l), internodes, panicle branches and glumes (Fig. 12m). On leaf blades, it causes short, linear, narrow, brown lesions that are parallel to the leaf veins. As plants approach maturity, leaf spotting can greatly increase on the more



Fig. 12k. Narrow brown leaf spot on leaf.

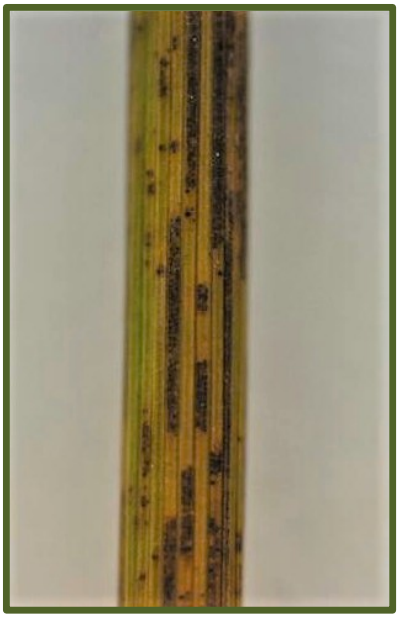


Fig. 12l. Narrow brown leaf spot on sheath.



Fig. 12m. Narrow brown leaf spot on glumes.

susceptible varieties and result in severe leaf blighting and premature death (Fig. 12n). Infection

of the leaf sheaths results in a large, brown blotch or "net blotch" caused by the browning of the leaf veins (Fig.12o). The fungus also can cause a "neck blight," where the internodal area above and below the node at the base of the panicle becomes light brown to tan (Fig. 12p). The affected area dies and the kernels in the lower portion of the panicle fail to fill. Low nitrogen levels increase the severity of this disease.

Varieties show different susceptibility to narrow brown leaf spot (Shi et al. 2021). Planting resistant varieties (Table 12d) is a good option for managing the disease. However, varietal resistance might not be durable or long-lasting since new pathogen races can develop quickly.



Fig. 12n. Narrow brown leaf spot causing leaf death.



Fig. 12o. Net blotch symptoms of narrow brown leaf spot.



Fig. 12p. Neck blight symptoms of narrow brown leaf spot.

Fungicides are available for control of this disease (Table 12c). When narrow brown leaf spot is severe enough to justify chemical control, Amistar Top®, Tilt®, PropiMax®, Bumper®, Stratego®, Quilt®, or QuitXcel® fungicides, containing propiconazole or difenoconazole active ingredient, should be applied in the late boot to heading stage (Uppala and Zhou 2018, 2019).

Brown Spot

Brown spot, caused by *Cochliobolus miyabeanus*, is one of the most common diseases of rice in Texas. The disease is present in seedlings and young and matured plants. The fungal pathogen attacks the coleoptiles, leaves, leaf sheaths, branches of the panicle, glumes, and grain. Although the disease is present at all rice growing stages, it does not necessarily cause significant economic losses. Significant yield losses can occur due to prolonged extremely wet weather, when unfavorable soil conditions such as N deficiency occurs, or when the pathogen attacks panicles.

Brown spot can attack seedlings, causing seedling blight. Lesions on leaves can be found throughout the growing season. The pathogen typically produces circular to oval lesions. The

lesions vary in size and color. On young leaves, spots are small, dark brown to reddish-brown (Fig. 12q). On older leaves, spots are relatively large and have a light brown to grey center surrounded by a reddish-brown margin and a gold halo (Fig. 12r). The lesions may coalesce, killing large areas of infected leaves. Brown spot is usually common in main and ratoon crops and can become severe as plants approach maturity. Symptoms on leaves, leaf sheaths, and hulls are similar. Symptoms also appear on glumes, causing black discoloration. The disease can reduce the number of grain per panicle and the weight of kernels.

Infected seed is the primary source of brown spot inoculum. However, the pathogen also can overwinter in infected crop debris. Brown spot tends to be severe on rice plants that are grown under N, P or K deficiency, or when abiotic or biotic stresses such as root damage and insect injury reduce the rice plant's ability to use N, P or K.

To minimize the damage caused by brown spot, the crop should receive recommended rates and timing of N and K, and proper soil and water management. Resistant varieties are available (Table 12b). Fungicide seed treatment can reduce primary fungal inoculum on seeds. Normally, fungicides are not recommended specifically for the control of brown spot. However, fungicides used to manage other foliar diseases may also be effective in reducing this disease.



Fig. 12q. Brown spot.



Fig. 12r. Brown spot.

Stem Rot

Stem rot is caused by a soil-borne fungus (*Sclerotium oryzae*) and is a significant problem in all U.S rice-producing states. The pathogen survives the winter as tiny seed-like structures called sclerotia, which can survive in the soil for up to 6 years, serving as the primary source for disease infection.

Stem rot is initiated when the sclerotia float to the water surface and infect the rice plant at the waterline. At first, small, rectangular, black lesions develop on the sheath (Fig. 12s). Later these lesions enlarge as the fungus penetrates inward toward the culm. In the later stages of crop maturity, large areas within infested fields may begin to lodge soon after drainage has begun.

Within infected culms and sheaths, numerous tiny, black sclerotia can be seen.



Fig. 12s. Stem rot (photo courtesy of D. Groth).

Although commercial long-grain rice varieties are generally susceptible to stem rot, the newer semidwarf varieties tend to be more tolerant to stem rot because of their resistance to lodging.

Some fungicides, when applied for sheath blight, can moderately suppress stem rot (Table 12c). However, currently registered fungicides do not adequately control stem rot and are not recommended for this purpose. Crop rotation, increased potassium levels, and lower nitrogen fertilization rates are recommended management practices for fields with a history of stem rot.

Crown (Black) Sheath Rot

Black sheath rot or crown sheath rot is caused by the soil-borne fungus *Gaeumannomyces graminis* var. *graminis* and has been in Texas rice fields for many years. Previously considered a minor disease of rice, it is becoming more of a problem with increasingly intensive production systems and shorter rotations. The disease usually is observed late in the main crop, but also has been found to infect the ratoon crop to some extent and can cause reduced tillering, poor grain fill, and lodging.

Infected plants show brown to black discoloration of the leaf sheaths from the crown to considerably above the water line (Fig. 12t). In the early stages of the infection, a dark, reddish-brown web of fungal mycelia (filaments) may be seen on the inward-facing surface of diseased leaf sheaths.



Fig. 12t. Crown (black) sheath rot (photo courtesy of D. Groth).

As the discolored, infected sheath tissue ages, fungal fruiting structures (perithecia) form within the tissue. The perithecia are tiny, black, globose structures imbedded in the sheath tissue, often with short beaks protruding through the surface. These perithecia are barely visible to the unaided eye and are about the size of a grain of black pepper.

Crop rotation, especially with non-grass crops, helps reduce the carryover of fungal inoculum. Thorough disking and maintaining a clean fallow field from the previous summer to planting allows plant residue to decompose which eliminates weed hosts upon which the pathogen survives.

Bacterial Panicle Blight

Bacterial panicle blight, caused by *Burkholderia glumae* and *B. gladioli*, is potentially a serious rice disease that may cause significant yield and quality losses in epidemic years. The causal agent of this disease was first described in Japan in 1967. Since then, it has been reported in several rice-producing regions and countries, including Latin America, the Philippines, and Vietnam. In the U.S., there was an outbreak of panicle blight in 1995 along the Gulf of Mexico. Historically, the

terms “panicle blight”, “panicle blighting” and “panicle blanking” have been used to describe the losses of rice yield caused by abiotic factors, including high temperatures and water stress, and unknown biotic factors for more than half a century in the U.S. In 2010, outbreaks of bacterial panicle blight and panicle blight occurred in Texas and other southern states. This increases the concern of the impacts of bacterial panicle blight on rice production.

Symptoms of bacterial panicle blight can be distinguished from common panicle blanking. Bacterial panicle blight occurs sporadically on individual plants or in circular or oval patterns in the field. In contrast, common panicle blanking, caused by abiotic stress such as from excessive heat, develops in the field more uniformly and does not form apparent foci (circular or oval patterns). Typical symptoms of bacterial panicle blight usually do not appear until the heading stage. The affected panicles range from relatively few to all developing grain being infested, which results in the panicle remaining upright (Fig. 12u). Infected florets initially have discoloration ranging from light green to light brown on the basal portion with a reddish-brown margin, separating this area from the rest of the floret, which eventually becomes straw-colored (Fig. 12v). The branches of the panicle remain green at the base of each floret, even after the glumes desiccate and turn tan (Fig. 12w). Florets at the latest stages of infection usually appear to be gray or black



Fig. 12u. Bacterial panicle blight.



Fig. 12v. Bacterial panicle blight on kernels.



Fig. 12w. Bacterial panicle blight.

due to the abundant growth of saprophytic fungi on the surface. The disease also can cause linear lesions on sheaths with a distinct reddish-brown border and a gray and necrotic center, resulting in sheath rot and stem rot. On the leaves, lesions are circular to oval-shaped with a smooth reddish-brown border and a gray or straw-colored center. If the infected plants are young, this disease can cause seedling blight. However, these symptoms on leaves, sheaths, stems, and seedlings are rarely observed under field conditions in the U.S.

Bacterial panicle blight is seedborne. The bacterial pathogen was found to be widely present in rice seed lots in studies conducted in Japan, the Philippines and the U.S. Infected rice seeds are believed to be the primary source of inoculum. The bacteria can inhabit the surface of plants and soils under a wide range of environments, which can serve as the sources of inoculum. The bacteria invade germinated seeds, inhabit the roots and lower sheaths, and move up the growing plant as

an epiphyte (an organism growing on a plant surface, but not as a parasite). Infection occurs at flowering by invading rice spikelets through stomata or wounds in the epidermis of glumes. The bacteria colonize and multiply in spikelets quickly after invasion by utilizing intermediate sugars in developing grain. The bacteria spread primarily by splashing water, windblown raindrops, and panicle contact, resulting in the formation of disease foci. High temperatures, especially nighttime temperatures, in combination with high humidity and frequent rain at the heading and flowering stages, are essential for the development of bacterial panicle blight epidemics. Bacterial panicle blight can cause severe disease in the main crop under these favorable disease development conditions. However, this disease rarely causes damage to the ratoon crop since the weather is relatively cool during this stage of crop growth.

Options for the management of bacterial panicle blight are very limited. No pesticides are currently labeled for use on rice for control in the U.S. Partially resistant varieties are available, although most commercially produced varieties are susceptible or very susceptible. Some varieties, such as Jasmine 85, Jupiter, and hybrids, are less susceptible (Table 12b). Proper cultural practices, including early planting or use of early maturing varieties to avoid the hottest times of the growing season, and avoiding excessive seeding and nitrogen rates, are helpful in reducing the damage caused by the disease. The use of pathogen-free seeds is an effective practice to reduce the incidence of bacterial panicle blight, but this practice has not been implemented in the U. S.

Panicle Blanking Complex

Florets that do not pollinate or fill properly can result from several biological and environmental factors. Often "blanked" florets can be numerous and result in significant yield losses. Research at the Texas A&M AgriLife Research Center at Beaumont and the International Rice Research Institute (IRRI) has shown that temperatures above 95°F during pollination (anthesis) cause floret sterility. Another high temperature-sensitive period that can cause pollen sterility occurs about 10 days before pollen is shed.

Early planting may be one way to reduce heat-induced sterility. Heat sterility should not be confused with bacterial panicle blight. In the case of bacterial panicle blight, infected florets often are pollinated but developing embryos abort, leaving a small embryo or undeveloped seed between the glumes. Upon close observation a few days after panicle exertion, a lack of luster in the green glumes of the affected panicle can be noticed. Within 1 to 2 weeks, the glumes turn various shades of tan to light brown and lack the turgidity and brightness of healthy glumes.

Three important characteristics of bacterial panicle blight separate it from other panicle disorders:

- Bacterial panicle blight often does not appear to prevent successful pollination
- Infected florets initially have discoloration ranging from light green to light brown on the basal portion with a reddish-brown margin, separating this area from the rest of the floret that becomes straw-colored later; and
- The rachis or branches of the panicle remain green for a while, right to the base of each floret, even after the glumes desiccate and turn tan.

Ear Blight

Ear blight is a disease complex caused by several fungi, including those that cause narrow brown leaf spot (*Cercospora janseana*) and brown spot (*Cochliobolus miyabeanus*). These fungi can cause discoloration and blight of the uppermost internodes, the neck below the panicle, the branches of the rachis, and spikelets of the panicles. Under disease-conducive weather conditions, these fungi also cause brown to black kernels, resulting from a mass of dark pathogen spores covering the kernels. This often results in poorly developed grain and low milling quality. Some fungicides applied in the mid to late booting stage help suppress ear blight.

False Smut

False smut is caused by the fungus *Ustilaginoidea virens*, which infects rice flowers from booting to early heading stages.

The infected florets are transformed into a velvety "smut ball" measuring up to a ½ inch in diameter. Immature smut balls appear orange and are covered with a thin membrane (Fig. 12x). At maturity, the membrane ruptures and exposes a mass of spores that quickly turn to a greenish-black powder.



Fig. 12x. False smut.

False smut has historically been a minor disease in Texas. However, it has raised concern since false smut was reported in Arkansas, from a few counties in 1997 to all rice-growing counties today. Economic damage can be immense since rice contaminated with false smut spores can be docked in price.

False smut management suggestions include the following:

- Plant rice as early as practical, due to late maturing fields appear to have more false smut
- Use recommended rates of nitrogen, due to the disease being more severe under high nitrogen fertility
- Tilt® applied at late boot gives some control of the disease, but this application is probably not economical unless mills start to dock growers for contaminated rice

Kernel Smut

Kernel smut is a serious disease caused by the fungus *Tilletia barclayana* (syn: *Neovossia horrida*). Kernel smut was considered a minor disease due to its nature of sporadic occurrence several decades ago. However, kernel smut has become a major disease in Texas and other states in recent years. From 2018 to 2021, this disease significantly affected rice production in Texas, Louisiana, Mississippi, and California. There has been an increasing trend of this disease in both incidence and severity over the last ten years. The fungus infects and replaces the endosperm of the rice grain completely or partially with a mass of black smut spores (Fig. 12y). Usually, only a few grains per

panicle are infected. However, up to 20% of kernels infected on up to 50% of panicles were observed in many fields in the epidemics of 2021. Kernel smut can occur on both main and ratoon crops but usually is more severe on the main crop.



Fig. 12y. Kernel smut.

Although yield losses are usually insignificant, monetary losses can be very high if the rice cannot be sold or the price is reduced at the mill. Infested lots of grain often have a dull, grayish cast caused by the smut spores. Rice lots exceeding 3% kernel smut infection presently do not qualify for a government loan.

The disease is not systemic. The smut spores fall to the soil surface, where they remain dormant until the following rice crop, or they can be introduced into a field with smut-contaminated rice seed. The smut spores float to the surface of the irrigation water where they germinate and produce air-borne spores that infect individual rice florets. Disease development is favored by frequent light showers and high relative humidity. Heavy nitrogen fertilization favors the disease.

Kernel smut is difficult to control. However, Propiconazole- or difenoconazole-containing fungicides do provide effective control (Table 12c). Field tests in Texas indicate that a mid-boot application of Amstar Top® (14 fl oz/ac), Quilt Xcel® (21 fl oz/ac) and Tilt® or Propimax® (10 fl oz/ac) reduces the number of smutted kernels. Proper timing of fungicide application is the key to controlling the disease. Mid-boot stage is the best time to apply a fungicide, while an application made at or after heading is ineffective. Fields planted with susceptible varieties that are over-fertilized with nitrogen may require two applications. The 1st application should be made at mid-boot, and the 2nd application should be followed 14 days later.

Some varieties (Table 12b) are less susceptible to the disease. The use of partially resistant varieties can reduce the damage caused by kernel smut. A 3-year crop rotation should reduce the number of smut spores present in the soil. Do not plant seed contaminated with smut spores since this disease is seedborne. Do not apply N fertilizer at an excessive amount since over N fertilization increases the susceptibility to kernel smut.

Straighthead

Straighthead is a physiological disorder that causes seeds to blank and heads to remain upright at maturity and generally occurs in spots scattered throughout the field. It is most easily recognized near harvest when normal plants have down-turned heads from the weight of the grain in the panicle, while affected plants remain upright. Hulls of affected grain are distorted into a crescent shape or “parrot beak” (Fig. 12z). Affected plants are darker green through the growing season and often produce shoots from lower nodes on the plant.

The disorder is more frequently found on sandy loam than on clay soils and has been associated with arsenic residues remaining in fields that were at one time planted with cotton. Straighthead is often found in fields where excessive non-decaying vegetation has been plowed under the soil soon before planting.

Control of straighthead is mainly achieved by planting resistant varieties (Table 12b). When planting a susceptible variety in fields with a history of straighthead, draining the field just before internode elongation provides some degree of control. Use caution when draining fields planted with a variety susceptible to blast, since blast can intensify in fields that are temporarily drained in the mid-season.



Fig. 12z. Straighthead.

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Insect Management

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Introduction

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Insects can attack the Texas rice crop from planting to harvest of both the main and ratoon crops. They can even attack rice after harvest, but this chapter will limit discussion to in-field pest problems. Furthermore, depending on the species of insect pest, all parts of the rice plant are vulnerable to damage including seeds, seedlings, roots, foliage, culms, tillers, and panicles. Thus, farmers and crop consultants must scout their fields from planting to harvest and take appropriate action in a timely manner to manage these arthropods effectively, safely, and economically. The bulk of this chapter will describe the major and some minor insect and mite pests of Texas rice, present pertinent information on their biology, and recommend management strategies and tactics. However, be aware that the information and management guidelines in this chapter are not "set in concrete" because agronomic practices change, insect and mite evolve, and introduced exotic pests can threaten rice crops at any time.

Integrated Pest Management (IPM)

IPM is a strategy that uses multiple tools to manage pests effectively and economically, while minimizing environmental disruption. In the case of rice in Texas, IPM relies mostly on insecticides, cultural controls, and host plant resistance. Insecticides are often the 1st line of defense because they are effective, quick acting, and require minimal effort on the part of the grower. IPM also includes the employment of economic injury levels (EILs) which is a population density of an insect pest that economically justifies the application of a control agent. For instance, if 10 insects per rice plant cause 100 lb per acre yield loss (in this case, a relationship which is discovered through research), and rice is selling for $10 per cwt, and the cost of the control agent is $20 per acre; then the EIL is 20 insects per rice plant. The goal of IPM is to apply the optimum amount of a control agent to minimize cost and environmental disruption while providing economically effective control.

Also, any control tactic must be feasible and mesh with current agronomic management practices. For example, research may show that draining rice fields controls rice water weevil. However, this tactic will not be adopted by farmers because draining causes loss of both fertilizers and herbicides, encourages grassy weed growth, predisposes rice to blast disease, and may not be effective if precipitation follows draining. Furthermore, agronomic practices change and evolve with time; consequently, IPM must adapt to these newer practices. Sometimes these changes result in a certain insect becoming a pest while a prior pest becomes of little concern. For example, in the past, many Texas rice farmers water-seeded to help control red rice. These early-flooded fields were susceptible to rice seed midge which is an aquatic insect that attacks rice seeds and young seedlings. Now, virtually all Texas rice is drill-planted (except organic rice) followed by a delayed flood. Thus, rice seed midge is no longer a problem under this type of irrigation and planting practice.

A bedrock of IPM is scouting and sampling. Rice can be attacked by insects from planting to harvest. Careful and frequent scouting and sampling either visually or by sweep net or another sampling tool is essential. Fields should be scouted as often as possible, but at least a weekly inspection is warranted. Farmers and consultants should drive around fields looking for areas that have poor stands or show discoloration or stunting. These areas justify closer inspection. Driving around a field is helpful because the position of the sun can affect the appearance and color of a field. For a given field, there is no set number of scouting locations, but if the field is rectangular, then each side should be scouted. Areas that are not the same as the rest of the field should be scouted. For instance, if an area of the field is adjacent to woods or a canal or pond, these areas should be scouted. Scouting the bottom as well as the top cuts is a good practice. Make sure to scout from the edge to about 100 ft or more into the field. When scouting, carry a hand lens, a phone to take pictures and a couple of plastic bags for insect/plant damage samples. Also, an ice chest is recommended for the insects/plant damage samples. Often farmers do not have the time or inclination to scout and sample their fields, so crop consultants can provide these services.

Regulatory Actions

The Texas Department of Agriculture (TDA) and the United States Environmental Protection Agency (USEPA) both play a crucial role in evaluating efficacy and environmental data relating to old and new insecticides. Texas A&M AgriLife Research provides data to TDA and USEPA to help them make informed decisions as to labeling or changing labels. Remember, these labels are legal documents, so abide by these labels. Over the years, some rice insecticides have been lost due to misuse and non-compliance with label instructions. The following is a brief historical summary of regulatory actions involving rice insecticides used in Texas from the late-1990s to the present (2020).

Furadan 3G (active ingredient carbofuran, a carbamate insecticide) was labeled to control the rice water weevil. USEPA withdrew the label in 1999 primarily due to bird kills associated with misuse of the pesticide.

Karate (active ingredient lambda-cyhalothrin, a pyrethroid insecticide) was labeled by USEPA in 1998 to control a variety of rice insect pests. In 2004, Karate Z was labeled to control the same array of rice pests but in a more concentrated form, less susceptible to breakdown by light, safer for handlers and more rain fast than Karate. In 2014/2015, Karate Z was replaced by Warrior II which has the same active ingredient and concentration as Karate Z.

Icon 6.2 FS (active ingredient fipronil, a phenylpyrazole insecticide) was labeled by USEPA as a seed treatment for the 1998 growing season. The primary target pest was the rice water weevil, but the EP found that it also provided good control of chinch bug and some control of stem borers. The company that makes Icon 6.2 FS voluntarily canceled the federal label in 2004 due to possible adverse effects on crayfish.

Dimilin 2L (active ingredient diflubenzuron, an insect growth regulator) was labeled by USEPA in 1999 to control the rice water weevil. The active ingredient sterilizes eggs developing in female adults and prevents larval emergence.

Fury (active ingredient zeta-cypermethrin, a pyrethroid insecticide) was labeled by USEPA in 2001 for an array of pests, including rice water weevil and rice stink bug. Fury is no longer available for use on rice; it was replaced by Mustang Maxx.

Mustang Maxx (active ingredient zeta-cypermethrin, a pyrethroid insecticide) was labeled by USEPA in 2003 to control an array of rice insect pests.

Prolex/Declare (active ingredient gamma-cyhalothrin, a pyrethroid insecticide) was labeled by USEPA in 2004 to control an array of rice insect pests. In 2012, Prolex was replaced by Declare. Both have the same active ingredient and concentration.

Trebon 3G (active ingredient etofenprox, a pyrethroid insecticide) was labeled by USEPA in 2009 to control the rice water weevil. Trebon 3G is a good option for farmers who grow rice close to crayfish or fishponds because it is less toxic to these organisms than most other labeled rice water weevil insecticides. In addition, the granular formulation minimizes drift to non-target areas. Recently, the manufacturer decided to withdraw Trebon 3G from the U.S. rice market due to marketing concerns.

Tenchu 20SG (active ingredient dinotefuran, a neonicotinoid insecticide) received a Crisis Exemption in 2008 and from 2009 through 2012 received Section 18 Emergency Exemptions for rice stink bug. In 2013, USEPA granted Tenchu 20SG a full federal label. Tenchu 20SG is systemic and Texas data show residual control of 7-11 days. Texas data also show Tenchu 20SG provides control of long-horned grasshoppers. In 2019, Tenchu 20SG was granted a 2(ee) Recommendation for use against the rice delphacid planthopper.

Cruiser Maxx/CruiserMaxx Rice (active ingredient thiamethoxam, a neonicotinoid insecticide) was approved for use as a seed treatment by USEPA in 2009 for control of rice water weevil, chinch bug, aphids, thrips, leafhoppers and grape colaspis (which is not a problem in Texas rice, but it is in Arkansas and Missouri rice). CruiserMaxx does not control stalk borers. In 2011, CruiserMaxx was replaced by CruiserMaxx Rice which contains thiamethoxam plus 3 fungicides in a single formulation. Thiamethoxam is systemic.

Dermacor X-100 (active ingredient chlorantraniliprole, a ryanoid insecticide) was approved for use in Texas under Section 18 Emergency Exemptions in 2008 and 2009. USEPA approved a full federal label for the 2010 growing season. The target pest for Dermacor X-100 is the rice water weevil. Dermacor X-100 provides excellent control of rice water weevil, as well as stalk borers when applied to seed at the recommended treatment rates relative to seeding rate (Table 13a). In short, Texas data show combinations of seeding and Dermacor X-100 treatment rates resulting in less than 0.06 lb active ingredient per acre may compromise control. Data from Texas also suggest Dermacor X-100 possesses fly larvae

Table 13a. Dermacor® X-100 seed treatment rates.

Dermacor® X-100 (fl oz per cwt seed)	Seeding rate (lbs per acre)		lb a.i. per acre range
	Low	High	
1.50	80	120	0.049 – 0.073
1.75	70	79	0.049 – 0.056
2.50	50	69	0.051 – 0.071
4.0-5.0	20	35	0.033 – 0.071-

(e.g., South American rice miner) activity. In addition, data from other sources indicate good activity against fall armyworm, but minimal activity against chinch bug or other insects with piercing-sucking mouthparts.

NipsIt INSIDE (active ingredient clothianidin, a neonicotinoid insecticide) is a seed treatment that is effective against the rice water weevil, grape colaspis, chinch bug, thrips, aphids, and other seedling pests with piercing-sucking mouthparts. In 2010 and 2011, NipsIt INSIDE was granted an Experimental Use Permit in Texas with the stipulation the maximum number of rice acres to be treated not exceed 10,000 per growing season. NipsIt INSIDE received a full federal USEPA label on rice in late 2012. NipsIt Suite Rice is a co-pack or custom blend of NipsIt INSIDE and the fungicides Sebring 318 FS and Spirato 480 FS applied to rice seed. Labeled rates in fl oz per cwt of seed are 1.92 for NipsIt INSIDE, 0.75-1.50 for Sebring 318 FS and 0.02-0.08 for Spirato 480 FS.

Belay (active ingredient clothianidin, a neonicotinoid insecticide) was approved by USEPA for use on rice in Texas and other southern rice-producing states in late 2012. Belay is applied as a foliar treatment primarily for control of rice water weevil, chinch bug, aphids, thrips, sharpshooters, and leafhoppers. Belay may also control rice stink bug and rice delphacid planthopper, but more research is needed to confirm preliminary research results.

Methyl Parathion (various formulations/Penncap-M) (active ingredient methyl parathion, an organophosphate insecticide) was used primarily to control rice stink bug. USEPA cancelled the use of methyl parathion on rice in 2013. It was deemed too toxic to non-target species.

Fastac EC (active ingredient alpha-cypermethrin, a pyrethroid insecticide) was approved by USEPA to control an array of rice insect pests, but the manufacturer stopped making it in 2015.

Endigo ZC (active ingredients lambda-cyhalothrin + thiamethoxam) was granted a Crisis Exemption to control the rice delphacid planthopper, an exotic pest of rice from Latin America, which was discovered attacking ratoon rice west and south of Harris Co. Endigo ZC in 2015. A request for a Quarantine Section 18 Emergency Exemption for Endigo ZC was submitted for use on both the main and ratoon crops in 2019. This was approved by USEPA, with additional Section 18s have been approved through 2025.

Tenchu 20SG was granted a 2(ee) Recommendation in 2019, which means it can be applied legally to control the rice planthopper. This insecticide already has a label for rice stink bug.

Fortenza (active ingredient cyantraniliprole, a ryanoid insecticide) was approved by USEPA for the 2019 rice-growing season. Fortenza is a seed treatment with good activity against rice water weevil. Texas data show it does not perform as well against stem borers as Dermacor-X-100.

In conclusion, research must continue to evaluate new insecticides in case insect resistance develops, USEPA cancels a rice label, or a manufacturer opts to withdraw/discontinue making a given insecticide.

Rice Water Weevil (*Lissorhoptrus oryzophilus*)

The rice water weevil (RWW) is a key pest of rice in the U.S. It is native to the southeastern U.S., but was introduced into California, Japan, the Korean Peninsula, Taiwan, and China. The insect is a type of beetle with chewing mouthparts on the end of a characteristic snout. The adult is about 1/8 to 3/16 inch-long (females are larger than males). They are dark brown to gray in color with a somewhat triangular dark spot on the top and front of the abdomen (Fig. 13a). The adults are good swimmers with hairs on the middle legs to help propel them through water. Adults overwinter in perennial clump grasses such as *Paspalum* spp., as well as in duff surrounding pine trees. When temperatures increase in the spring, adults fly to rice fields and feed on seedling rice foliage. Adult feeding scars occur on the foliage and are linear and of varying length. In general, these feeding scars are not injurious, but sometimes under flooded conditions (water-seeded rice) heavy infestations of adults can kill seedling rice. Once the permanent flood is applied, females lay eggs underwater in the sheaths of small developing culms. Eggs hatch and larvae move to the roots where they progress through 4 instars before pupating in a mud cell shaped like a miniature football (Fig. 13b). The largest larvae (4th instar) are about 1/4 to 5/16 inch-long. They are legless and white with chewing mouthparts. In SE Texas, the RWW has multiple generations, but the generation that feeds on rice in the spring is the most damaging. RWWs also attack the ratoon crop, but damage is much less compared to the main crop. Control of RWW on the main crop can benefit the ratoon crop; however, insecticidal control of RWW on the ratoon crop is not recommended.



Fig. 13a. Adult rice water weevil (photo courtesy of J.K. Clark).

RWWs are attracted to flooded rice, so females lay most of their eggs within the first 2 weeks following a flood. Females are parthenogenetic which means they do not have to mate to produce eggs. The earlier the flood is applied relative to emergence of rice through the soil, the more potential damage by RWW. Thin stands and deep water are also associated with more RWW damage. Thus, rice plants in flooded areas around water boxes and in borrow ditches often suffer severe damage. Furthermore, agronomic practices that encourage a good stand of rice (increased seeding rate, preparation of a good seedbed, etc.) will ameliorate RWW damage. Precision leveled fields discourage RWW build-up because these fields are more apt to drain well after a rain or flush (no flooded potholes). Areas of fields that remain submerged after a rain or flush result in continued feeding by RWW larvae. In the past, some farmers drained fields to dry out soil to kill immature RWWs. However, this practice is not recommended because draining fields can lead to blast outbreaks, and loss of fertilizer and herbicide activity. Research in Texas has found that RWW damage is not confined to the margins of rice fields like in California, so strip treatments targeting the margins of fields is not recommended in Texas.



Fig. 13b. Rice water weevil larvae and pupa (photo courtesy of J.K. Clark).

An average of 1 immature RWW per core (4-inch diameter by 4-inch-deep plug of mud and rice roots) reduces yield 75 lb/acre or about 1% of a projected yield of 7,500 lb/acre (Fig. 13c). This relationship is mostly linear; thus, 10 immatures per core will reduce yield approximately 750 lb/acre (Fig. 13d). Virtually all RWW-unprotected rice fields in Texas harbor higher than EILs; thus, effective seed treatments are generally economically justified. Table 13b shows the EILs for RWW based on projected yield, price of rough rice, and cost of control. Higher yields and higher rice prices mean lower EILs while higher control costs mean higher EILs which are based on larval/pupal densities 3 weeks after flood. The relatively low larval threshold densities throughout the table show the importance of controlling RWW. However, the stage of crop growth during which injury occurs greatly affects crop tolerance for root injury and optimal timing of RWW control (Wu and Wilson 1997). This research also suggests thresholds may be too high when infestations begin during early stages of tillering.

A reliable quantitative relationship has not been detected between adult RWW feeding scars, larval population density, and crop damage. However, if feeding scars are abundant prior to or soon after flood, larval populations may be high (Fig. 13e).



Fig. 13c. Immature rice water weevil core sampler and screen bucket.



Fig. 13d. Rice water weevil damage – Protec protected (right).



Fig. 13e. Adult rice water weevil feeding scars.

For research purposes, a core tool is used to sample immature RWW populations 3 weeks after flood and 7-10 days later. Immature RWW populations are at their highest at this stage of crop growth. This sampling method is not recommended for farmers, scouts, or crop consultants because, by this time, most RWW damage has occurred.

Table 13b. Economic injury levels (number of larvae/pupae per core) for rice water weevil.

Estimated main crop yield (lbs per acre)	Rough rice price ($ per cwt)	Cost of control ($ per acre)				
		10	15	20	25	30
5,000	6	4.0	6.1	8.1	10.1	12.1
	12	2.0	3.0	4.0	5.0	6.1
	18	1.3	2.0	2.7	3.4	4.0
	24	1.0	1.5	2.0	2.5	3.0
6,000	6	3.0	4.5	6.1	7.6	9.1
	12	1.5	2.3	3.0	3.8	4.5
	18	1.0	1.5	2.0	2.5	3.0
	24	0.8	1.1	1.5	1.9	2.3
7,500	6	2.4	3.6	4.8	6.1	7.3
	12	1.2	1.8	2.4	3.0	3.6
	18	0.8	1.2	1.6	2.0	2.4
	24	0.6	0.9	1.2	1.5	1.8
8,500	6	2.1	3.2	4.3	7	6.4
	12	1.1	1.6	2.1	2.7	3.2
	18	0.7	1.1	1.4	1.8	2.1
	24	0.5	0.8	1.1	1.3	1.6

Table 13c. Insecticides for rice water weevil control.

Active ingredient	Rate per acre		Timing of applications
chlorantraniliprole Dermacor X-100	See Table 13a		Apply to dry seed
diflubenzuron Dimilin 2L	0.19–0.25 lb 0.13 lb per application	12.0–16.0 fl oz 8.0 fl oz per application	**Delayed flood:** 2 to 5 days after flood. **Pinpoint/continuous flood:** At time of emergence through water to 5 days later, when adults are active in field, and a second application 5 to 7 days after the first application.
Cyantraniliprole Fortenza	Depends on seeding rate	3.47 fl oz/cwt	Apply to dry seed.
Lambda-cyhalothrin Warrior II	0.025–0.04 lb	1.6–2.56 fl oz	**Delayed flood:** At time of flood to 5 days later. Recent Texas data show application immediately before flood does not provide as effective control as in the past. **Pinpoint/continuous flood:** At time of emergence through the water to 1 week later, when adults are active in field, and a second application 7 to 10 days after the first application.
Thiamethoxam CruiserMaxx Rice	Depends on seeding rate	7.0 fl oz/cwt (a fl oz contains 9.1 g thiamethoxam, 0.1 g fludioxonil, 0.46 g azoxystrobin and 0.57 g mefenoxam)	Apply to dry seed.
Clothianidin BELAY	0.075 lb	4.5 fl oz	**Delayed flood:** At time of flood to 10 days after flood.
Clothianidin NipsIt INSIDE[1]	Depends on seeding rate	1.92 fl oz/cwt	Apply to dry seed.
Zeta-cypermethrin Mustang Maxx	0.02–0.025 lb	3.2–4.0 fl oz	**Delayed flood:** At time of permanent flood to 5 days later. Recent Texas data show application immediately before flood does not provide as effective control as in the past. **Pinpoint/continuous flood:** At time of emergence through the water to 1 week later, when adults are active in field, and a second application 7 to 10 days after the first application.

[1] NipsIt SUITE Rice is available as a seed treatment and contains the same amount of clothianidin as NipsIt INSIDE. It also contains 2 fungicides---Sebring and Spirato---which must be added separately to the clothianidin during the seed treatment process.

For additional information on the above products, read the labels or contact Texas A&M AgriLife Research at lina.bernaola@ag.tamu.edu.

Control Alternatives Other than Insecticides for RWW

Occasionally, populations of larvae can be reduced by draining fields, but this is not recommended due to reasons described above. Research shows the highest populations are associated with optimum planting dates (mid-March to mid-April). So, adjusting planting date to help control RWW is offset by the reduction in yield due to planting outside the optimum planting window. Planting late can also negatively affect ratoon crop yields.

Research in Texas shows the addition of extra N applied preflood or at panicle differentiation did not affect RWW damage. Research from Louisiana found that a shallow flood can reduce oviposition. A deep flood combined with a thin stand is very conducive to producing unacceptable losses due to RWW. Precision-leveling rice fields is a good way to save water and labor, increase yield and help manage RWW. Shallow floods can be more easily achieved and maintained in precision-leveled fields which have fewer levees and borrow ditches where deep water and increased RWW populations occur.

Natural or biological control can help reduce RWW populations. Unfortunately, research to date has not detected a biological agent(s) that can significantly affect RWW densities. A fungus, *Beauvaria bassiana*, attacks overwintering adults, but probably does not impact densities of populations infesting rice. Rodents also feed on overwintering adults, but again, insect mortality caused by rodents is thought to be minimal. A mermithid nematode has been found infecting the gut of overwintering RWWs, but infection rates are low. In addition, commercial formulations of nematodes, *Bacillus* spp., and *Beauvaria* sp. provide only limited control. The insect diapauses, which is a quiescent state, when temperatures begin to cool, and day length decreases to a threshold level. Diapause helps the insect survive unfavorable winter conditions here and elsewhere in its global distribution.

Chinch Bug (*Blissus leucopterus leucopterus*)

The adult chinch bug is about 3/16 inch long and black with white wings that overlap to give the appearance of a white "X" on the body (Fig. 13f). The early-stage nymphs are reddish and shaped like the adults. The insect proceeds through 5 nymphal stages before becoming an adult. Eggs are often inserted into the sheaths of young rice seedlings near ground level (Fig 13g). The eggs are often laid in a row parallel to the veins with the end of the eggs protruding from the sheaths. It takes about 1 month for development from egg to adult, so this insect can produce multiple generations during a growing season. Chinch bug damage consists of yellowing, stippling, and striping of foliage caused by removal of plant juices and damage to tissue using piercing-sucking mouthparts. Affected seedlings can also be stunted. The worst and most frequent damage occur to seedling rice which can cause stand loss. This is particularly relevant to hybrid rice fields which are planted at a low seeding rate. Thus, fields should be inspected for chinch bugs and damage as soon as rice emerges through the soil. Searching for the insect can be



Fig. 13f. Adult chinch bugs on rice culm.



Fig. 13g. Chinch bug eggs laid in rice culm.

difficult. During the heat of the day, they crawl down through soil cracks where they can still feed on rice roots and crowns. They seem to prefer heavier clay soils which crack upon drying providing shelter and moisture. Lighter soils do not crack as readily and lose moisture rapidly. Thus, if inspecting for chinch bugs during the heat of the day, grasp the seedling close to the ground and wiggle the plant back and forth which will cause the chinch bug(s) to move and be visible. For young seedling rice, the treatment threshold is 1 adult per 2 seedlings (Fig. 13h). As rice grows past the seedling stage, damage is less severe (Fig 13i). Research has shown that damage is exacerbated by herbicide phytotoxicity. For instance, chinch bug damage followed by injury from a propanil application can kill rice. This is called a negative synergistic response. In addition, rice is more affected when chinch bugs feed near the ground level. Thus, applying a flush or flood moves the insects up the rice plants resulting in less potential for further damage. Chinch bugs also attack later stages of rice. Very high populations of the insect can occur causing extensive yellowing of rice. Later infestations frequently start at the edges of fields and originate from nearby pastures and gassy weedy margins of fields. When these weeds and pasture grasses die or are mowed, chinch bugs move into adjoining rice. The seed treatments NipsIt INSIDE and CruiserMaxx Rice are effective against the chinch bug, but not the seed treatment Dermacor X-100 (Table 13d).



Fig. 13h. Chinch bug density experiment.



Fig. 13i. Chinch bug damage in commercial rice field.

Table 13d. Insecticides for chinch bug control.

Active ingredient	Rate per acre		Timing of applications
carbaryl Sevin XLR Plus	1.0–1.5 lb	1-1.5 qt	Apply when adult populations approach an average of one per two seedlings.
Lambda-cyhalothrin Warrior II	0.025–0.04 lb	1.6–2.56 fl oz	Apply when adult populations approach an average of one per two seedlings.
Thiamethoxam CruiserMaxx Rice	Depends on seeding rate	7.0 fl oz/cwt (Each fl oz contains 9.1 g thiamethoxam, 0.1 g fludioxonil, 0.46 g azoxystrobin and 0.57 g mefenoxam)	Apply to dry seed.
Clothianidin BELAY	0.075 lb	4.5 fl oz	Apply when adult populations approach an average of one per two seedlings.
Clothianidin NipsIt INSIDE[1]	Depends on seeding rate	1.92 fl oz/cwt	Apply to dry seed.
Zeta-cypermethrin Mustang Maxx	0.0165–0.025 lb	2.64–4.0 fl oz	Apply when adult populations approach an average of one per two seedlings.

[1] NipsIt SUITE Rice is available as a seed treatment and contains the same amount of clothianidin as NipsIt INSIDE. It also contains 2 fungicides---Sebring and Spirato---which must be added separately to the clothianidin during the seed treatment process.
For additional information on the above products, read the labels or contact Texas A&M AgriLife Research at lina.bernaola@ag.tamu.edu.

Fall Armyworm *(Spodoptera frugiperda)*

All life stages of the fall armyworm can survive along the Gulf Coast during the winter when the larvae feed on grain crops, grasses, and other weeds. Rice is most often attacked during the seedling and early tillering stages prior to flooding. However, recent infestations have been reported on main and ratoon crop rice after flooding. Crop consultants east of Harris Co. report damaging main crop infestations often are observed in mid-May The fall armyworm is a moth that lays eggs at night in masses on rice foliage. The eggs hatch and the larvae (armyworms) consume rice leaves. Damage can be localized or can be spread throughout fields because moths are strong fliers. After passing through 5-6 instars (each successive instar is larger and consumes more



Fig. 13j. Fall armyworm larva and damage.

foliage), the larvae pupate (Fig. 13j). Late instar larvae have an inverted "Y" on their head capsule, so this species is easy to identify. Normally, pupation takes place in the ground, but if rice is flooded, pupae can't survive. Small larvae are difficult to detect. Older larvae feed on leaf blades and can severely reduce plant stands. Some producers detect infestations by observing cattle egrets feeding on larvae or by noticing larvae adhering to their boots when walking through fields. These are not recommended methods of scouting for larval infestations because by this time considerable damage has likely occurred. So, fields should be scouted for fall armyworm larvae from emergence to harvest, but the most critical time is during seedling to tillering stages. Recent observations show fall armyworm can also attack the ratoon crop. Research has not been conducted on controlling fall armyworm in the ratoon crop, but producer observations suggest Dermacor X-100 seed treatment provides some degree of control of fall armyworm on both the main and ratoon crop; but research is needed to confirm and quantify these observations. When an infestation is detected, the field can be flooded to force larvae up the rice plant and restrict feeding and movement within the field, thereby reducing plant damage. Flooding or increasing flood depth exposes larvae to harsh environmental conditions and natural control agents such as spiders, fungal and bacterial pathogens, wasps, birds, and an insect parasite, *Cotesia* sp. This small black wasp lays its egg in the fall armyworm larva. The egg hatches and the parasitoid larva feeds on the host larva, eventually killing it. The cocoon of the wasp is white, somewhat fuzzy and shaped like a small football and can often be seen on the upper sides of rice leaves. Infestations are generally more severe in late-planted rice fields and in fields adjacent to pastures or grassy areas. As previously mentioned, fall armyworms can attack the ratoon crop, so scouting must be conducted throughout the development of both crops.

Stands can be reduced by larvae attacking rice seedlings before flooding. Research in California showed larval feeding exceeding 25% defoliation just prior to or at heading can reduce yield significantly. In Arkansas, control is recommended when there are 3 or more worms per square foot. In Texas, the suggested time for applying an insecticide before flooding is when larvae are present and stands are threatened, or after flooding when larvae are present and average defoliation approaches 25%. See Table 13e for recommended insecticides and rates.

Table 13e. Insecticides for fall armyworm control.

Active ingredient/product	Rate per acre		Timing of applications
	Active ingredient	Product	
carbaryl Sevin XLR Plus	1.0–1.5 lb	1–1½ qt	Apply when extensive defoliation occurs, and larvae are present.
Chlorantraniliprole Dermacor X-100	See Table 13a		Apply to dry seed.
Lambda-cyhalothrin Warrior II	0.025–0.04 lb	1.6–2.56 fl oz	Apply when extensive defoliation occurs, and larvae are present.
Zeta-cypermethrin Mustang Maxx	0.0165–0.025 lb	2.64–4.0 fl oz	Apply when extensive defoliation occurs, and larvae are present.

For additional information on the above products, read the labels or contact Texas A&M AgriLife Research at lina.bernaola@ag.tamu.edu.

Grasshoppers

Several grasshopper species attack rice. The most abundant is the meadow grasshopper, *Conocephalus fasciatus* (Fig. 13k). This insect is ⅞ to 1⅛ inches long, feeds on rice leaves, flowers, grain, and invertebrates. This species is also called a katydid or long-horned grasshopper because it has long antennae. A potentially more serious pest is the differential grasshopper, *Melanoplus differentialis*. It is larger (1 ¼ to 1 ½ inches long), light brown to yellowish with two black bands on the inside of each jumping leg. The antennae are short; thus, it is sometimes called a short-horned grasshopper. Both long- and short-horned grasshoppers have chewing mouthparts. Damage includes defoliation and sometimes biting of pedicels and branches attached to individual grain which causes blank, white grain beyond the bites. Grasshoppers enter rice fields from the margins where they mainly feed on weeds. Consequently, populations of grasshoppers are usually higher near the edges of rice fields. For this reason, scouting for grasshoppers should extend farther into fields than the edges. Although grasshoppers are common in rice fields, economic damage due to grasshopper feeding has not been observed in Texas. Remember, long-horned grasshoppers can be beneficial since they also feed on pest insects.

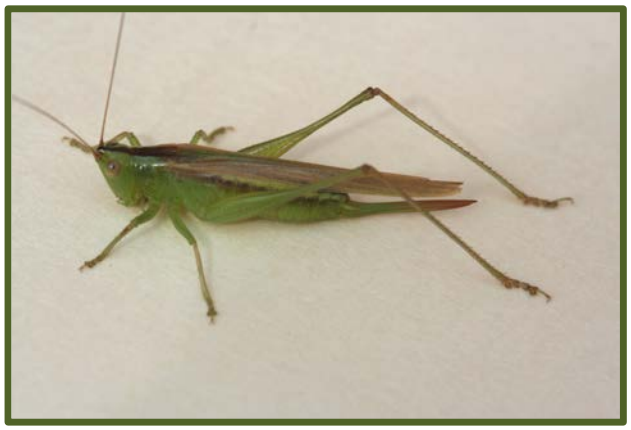


Fig. 13k. Adult long-horned grasshopper.

In Arkansas, control is recommended when 7 to 10 grasshoppers are observed per square yard, accompanied by excessive leaf loss. In Mississippi, control measures are suggested only after grasshoppers occur on 10 or more heads per 100 heads inspected.

Table 13f. Insecticides for grasshopper control.

Active ingredient/product	Rate per acre		Timing of applications
	Active ingredient	Product	
carbaryl Sevin XLR Plus	1.0–1.5 lb		Generally, grasshoppers do not cause economic damage. Apply when defoliation or stem and panicle damage is excessive.
lambda-cyhalothrin Warrior II	0.025–0.04 lb	1.6–2.56 fl oz	
zeta-cypermethrin Mustang Maxx	0.020–0.025 lb	3.2–4.0 fl oz	

For additional information on the above products, read the labels or contact Texas A&M AgriLife Research at lina.bernaola@ag.tamu.edu.

Rice Stink Bug *(Oebalus pugnax)*

The rice stink bug (RSB) is another key pest of Texas rice. Like the RWW, the RSB is native to the southeastern U.S. Adults overwinter near the ground in grasses or under leaf litter. In the spring, the straw-colored, ⅜ to ½ inch long, shield-shaped adults become active and deposit green, barrel-shaped eggs in two parallel rows on foliage and panicles of grasses (Fig. 13l). Each egg mass is comprised of up to 50 eggs. Nymphs hatching from these eggs are at first bright red with black markings, but with age they become tan colored with intricate red and black patterns on the top of their abdomens (Fig. 7l and 7m). Unlike adults, nymphs have neither wings nor forward-pointing spines behind their heads. Multiple generations of RSB can develop on grass hosts before rice begins to head. Heading rice attracts the adults which are strong fliers. Sorghum fields can harbor high populations of RSBs. Furthermore, sorghum harvest often coincides with rice heading resulting in high numbers of adult RSBs moving from harvested sorghum fields to nearby rice fields. Frequent and thorough scouting for RSB is recommended when rice begins to head, particularly if rice is near sorghum. Scouting is normally performed with a sweep net, as described below. RSBs release a pungent odor when disturbed, so a sweep net containing RSBs will give off this odor when the net is inspected. Generally, RSB populations are higher near the edges of rice fields. So, be sure to scout fields near the edges and farther into fields to better estimate population densities.



Fig. 13l. Rice stink bug eggs and 1st instar nymphs.



Fig. 13m. Rice stink bug nymph.

RSB feeding reduces grain quality (Fig. 13n). However, cage experiments with varying levels of RSB densities at various rice maturation stages suggest no reduction in grain yield (Fig. 13o). Thus, the main damage caused by the RSB is "peck" which is an imperfection of the grain most easily recognized by a "bullseye" discoloration evident in brown and milled rice. Pathogenic microorganisms (e.g., fungi) found on the stylets (piercing-sucking mouthparts) of RSBs and on the hulls of rice grain are introduced into the grain when the insect feeds. The RSB injects saliva into the grain to help liquefy the contents which are then sucked up. So, the combination of feeding and microorganism activity leads to pecky grain. The presence of discolored grain can lower the grade and market



Fig. 13n. Pecky rice (photo courtesy of J. Saichuk).

value of the rice. The damage is much more pronounced on milled, parboiled kernels. A high percentage of peck also has been correlated with reduced head yield in milled rice.



Fig. 13o. Rice stink bug adult (photo courtesy of K. Tindall).

The percentage of peck in a graded lot of rice represents a broad range of grain imperfections that may not be caused solely by the RSB. Research has shown that even when preventive RSB control programs are conducted, graders often find some level of peck. Other causes could include plant pathogens, genetic imperfections, environmental stress during grain development, and late harvest. Data from Arkansas show that long, medium, and short grain varieties exhibit the least to the most amount of peck, respectively. Logically, the longer the period from heading to harvest, the greater the likelihood of suffering peck damage. In general, long grain varieties exhibit a shorter period of vulnerability than medium or short grain varieties.

Recent research revealed rice in Florida is attacked by 3 species of stink bugs; *Oebalus pugnax* (the common species in Texas rice fields) and 2 exotic species: *Oebalus insularis* and *Oebalus ypsilongriseus.* Research conducted in Texas in 2020 found a single adult *Oebalus insularis* in a rice field in Jefferson Co. With the help of crop consultants, we will continue to monitor Texas rice fields for the 2 exotic stink bug species.

Sampling Techniques and Treatment Thresholds

Scout rice fields from heading to dough and apply insecticides only when RSB populations exceed treatment thresholds. The most vulnerable stages of rice maturation to RSB and peck are heading and milk. Thus, concentrate your sampling efforts during these stages.

Direct Observation Method - In Arkansas, a treatment threshold has been established based on randomly checking 100 heads of rice with binoculars. Treatment is recommended when 10 or more RSBs per 100 heads are observed. However, this threshold has not been confirmed in Texas.

Sweep Net Sampling - A recommended technique for sampling RSB populations is to use a 15-inch diameter insect sweep net connected to a 2 ft handle When 50% of the panicles have emerged (headed), sample the fields once or twice a week until harvest. Sample when the foliage is not wet from dew or rain. While walking through the field, make 10 consecutive (180 degree) sweeps. Swing the net from side to side with each step. Be sure to sweep so that the top of the net is even with the top of the panicles. After 10 successive sweeps, count the adult RSBs as they are removed from the net (Fig. 13p). Normally, 10 samples of 10 consecutive sweeps are made in a field to estimate the population. Then calculate the average number of



Fig. 13p. Sweep net with rice stink bugs and long-horned grasshoppers.

RSBs caught per 10 sweeps. However, in recent years, farmers have been producing very high yielding crops with both hybrid and conventional varieties. These high yielding crops have dense canopies which make walking through them physically difficult. So, some crop consultants now take a 180-degree sweep, stop, close the net, move 2-3 steps forward, then take another sweep, and repeat until 10 sweeps are taken. The net contents are then counted. Obviously, this sampling methodology can yield far different results than the methodology explained above. Research is needed to compare the results obtained with the 2 sampling methodologies.

Formerly, an insecticide application was justified when infestation levels reached or exceeded 5 or more RSB adults per 10 sweeps during heading and milk. Thereafter, insecticide applications were applied when 10 or more adults per 10 sweeps were collected. Revised treatment thresholds are discussed below.

Visual Sampling - An alternative to sweep net sampling is the use of a 5-foot sweep stick to estimate visually the RSB population level. This method of sampling requires less effort, especially now that many high-yielding fields with dense canopies are common.

Sweep the stick 180 degrees from one side to the other, lightly disturbing the tops of the panicles. While doing this, count the number of adult RSBs observed on the rice or in flight from the area disturbed by the entire length of the stick. Repeat this process for a total of 10 sweep stick sweeps per field and calculate the average number of adult RSBs per sweep stick sweep.

The relationship between sweep stick and sweep net counts is given by this formula:

$SN = (SS + 0.156) \div 0.675$

where SN = number of adult RSBs caught after 10 sweeps with a 15-inch diameter sweep net connected to a 2-ft handle, SS = number of adult RSBs observed after one sweep of the sweep stick. Using this formula enables you to transform the sweep stick counts into number of insects caught with the sweep net.

When visually sampling for RSBs using the sweep stick, follow the same general recommendations given for sweep net sampling, in terms of where to sample and how many samples to take.

Sequential Sampling - Sequential sampling is used to classify an insect population as exceeding or not exceeding a treatment threshold. If the threshold is exceeded, a management action is needed. With sequential sampling, fewer sample units than conventional sampling usually are required to reach a decision (Espino et al. 2008). Tables 13g-h present sequential sampling plans for the RSB for sweep net and visual sampling. These plans have been created for commonly used treatment thresholds in the Texas Rice Belt: 5 adult RSBs per 10 sweep net sweeps or 3.2 adult RSBs per sweep stick sweep for heading and milk; and 10 adult RSBs per 10 sweep net sweeps or 6.6 adult RSBs per sweep stick sweep for soft dough.

The following steps describe how to use the sequential sampling tables.

- Choose the table corresponding to the sampling method to be used and the treatment threshold relevant to the stage of the crop.

- Choose the level of risk. A 20% risk level means that out of 10 samples, there is a probability of reaching a wrong decision 2 times. A lower risk will require taking more sample units.
- After 4 sample units have been taken, determine the cumulative number of adult RSBs caught or observed and locate the column that corresponds to this number (a sample unit is 10 sweep net sweeps or one sweep stick sweep). If the cumulative number is in the "stop sampling" column, then additional sampling is not required, and a decision is reached. If the cumulative number is in the "continue sampling" column, then you need additional sampling.
- Repeat the process until the cumulative number obtained falls in the "stop sampling" column. If no decision is reached by the 10th sample unit, sample again in a day or two.

Table 13g. Sequential sampling table for sampling rice stink bugs using the sweep net method (Economic threshold = 5 adult rice stink bugs/10 sweeps, heading and milk stages).

	Cumulative number of adult rice stink bugs					
	10% risk			20% risk		
Sample unit number	Stop sampling, control action not needed	Continue sampling	Stop sampling, control action needed	Stop sampling, control action not needed	Continue sampling	Stop sampling, control action needed
4	14 or fewer	15–33	34 or more	16 or fewer	17–26	27 or more
5	18 or fewer	19–38	39 or more	20 or fewer	21–32	33 or more
6	22 or fewer	23–43	44 or more	25 or fewer	26–37	38 or more
7	27 or fewer	28–48	49 or more	30 or fewer	31–42	43 or more
8	31 or fewer	32–54	55 or more	34 or fewer	35–48	49 or more
9	36 or fewer	37–59	60 or more	39 or fewer	40–53	54 or more
10	40 or fewer	–	65 or more	43 or fewer	–	59 or more

Table 13h. Sequential sampling table for sampling rice stink bugs using the visual method (Economic threshold = 3.2 adult rice stink bugs/sweep stick sweep, heading and milk stages).

	Cumulative number of adult rice stink bugs					
	10% risk			20% risk		
Sample unit number	Stop sampling, control action not needed	Continue sampling	Stop sampling, control action needed	Stop sampling, control action not needed	Continue sampling	Stop sampling, control action needed
4	8 or fewer	9–21	22 or more	10 or fewer	11–17	18 or more
5	11 or fewer	12–24	25 or more	13 or fewer	14–21	22 or more
6	14 or fewer	15–28	29 or more	16 or fewer	17–24	25 or more
7	17 or fewer	18–31	32 or more	19 or fewer	20–27	28 or more
8	20 or fewer	21–35	36 or more	22 or fewer	23–31	32 or more
9	22 or fewer	23–38	39 or more	25 or fewer	26–34	35 or more
10	25 or fewer	–	43 or more	28 or fewer	–	39 or more

Revised Treatment Thresholds - Experiments conducted in Texas in 2005 and 2006 were designed to determine if treatment thresholds for RSB needed revising (Espino et al. 2007). The old treatment thresholds were based on obsolete varieties and cultural practices and outdated market conditions. The experiments conducted in 2005 and 2006 used Cocodrie grown according to recommended production practices using field cages infested with RSBs during different stages of grain maturation. The results of these experiments differ markedly from those of older experiments.

Basically, results suggest RSB does not reduce grain or head rice yield, given population densities that were encountered. Thus, the primary damage caused by RSB is peck. Results also show that late instar nymphs can cause significant peck but not as much as adults. All stages of grain maturation (heading, milk, soft dough, and hard dough) are susceptible to RSB damage, but the earlier an infestation develops, the more likely it is that a higher level of peck will develop. Thus, in general, controlling infestations during the heading and milk stages is very crucial to managing peck. Also, early populations of RSB, if left uncontrolled, have more time to feed on grain, which can lead to more peck. In addition, higher yields mean more grain is available for RSB feeding which implies that RSB damage can be diluted by increasing yield. Evidence does not show that high-yielding fields attract more RSBs. Certain conditions and assumptions are crucial to these revised treatment thresholds:

- The goal is to prevent peck from exceeding 3.5% by weight in brown rice and 1.5% by weight in milled rice, which represents U.S. Grade 1 or 2. Red rice is lumped in with peck in the grading system. Grade 3 rice is discounted 30 cents per cwt when red rice + peck exceeds 3.5% in brown and 1.5% in milled. Thus, given a yield of 8,000 lb/acre dry, the discount equals $24 per acre. For a U.S. Grade 4, peck + red rice must exceed 5% in brown and 2.5% in milled. Grade 4 rice is discounted 60 cents per cwt. Thus, given the same yield, the discount equals $48 per acre.
- RSBs do not affect grain yield or head rice yield
- If left uncontrolled, RSB populations will remain at the same level throughout the entire grain maturation period
- More grain in a field (i.e., higher yields) dilutes RSB damage
- Higher yielding fields do not attract more RSBs or cause a change in the feeding behavior of them
- Sweep net efficiency is 15%. For instance, if 10 RSBs are collected in 10 sweeps, then about 67 RSBs are in the area sampled.

Table 13i shows the revised treatment thresholds based on sweep net sampling. When using the sweep net, take 10 consecutive sweeps (one sweep per one step), which is a sample unit. Make sure each sweep covers a 180˚ arc. The top of the net should be level with the tops of the panicles. Take at least four, 10-sweep sample units per field and don't sample near field margins. Sample units should be distributed over the field. Sample fields at least at the beginning of each grain development stage (heading, milk, soft dough, and hard dough). To use Table 13i, average your sweep net counts for a field. Counts include adult and large nymphs (4^{th} and 5^{th} instars). If your average count per 10 sweeps exceeds the appropriate value in the table, spray. For instance, if you

expect a yield of 7,500 pounds per acre and rice is heading, spray your field when your average count is 13 or more RSB adults and large nymphs per 10 sweeps. Keep in mind that these treatment thresholds should be used as a guide on how to manage RSBs. As additional data become available, these treatment thresholds may change.

Table 13i Insecticides for rice stink bug control.

Active ingredient/product	Rate per acre		Timing of applications
	Active ingredient	Product	
carbaryl Sevin XLR Plus	1.0–1.5 lb	1-1/2 qt	Apply from heading to near harvest when adult rice stink bug populations reach threshold levels.
Dinotefuran Tenchu 20SG	0.094–0.131 lb	7.5–10.5 oz	
lambda-cyhalothrin Warrior II	0.025–0.04 lb	1.6–2.56 fl oz	
zeta-cypermethrin Mustang Maxx	0.0165–0.025 lb	2.64–4.0 fl oz	

For additional information on these products, read the labels or contact Texas A&M AgriLife Research at (409) 752-2741.

As mentioned before, there is a need to revise treatment thresholds for RSB based on newer varieties, including conventional and hybrid. These future revised thresholds should also be based on current sampling methodologies employed by crop consultants in the Texas Rice Belt. Finally, RSBs also attack the ratoon crop, but research has not been conducted to determine treatment thresholds.

Insecticidal Management - Recent research indicates the RSB has developed some resistance to lambda-cyhalothrin (Warrior II) and possibly other pyrethroids in Texas (especially in Wharton Co. near Round Mott). Pyrethroids are not systemic; they kill by contact only. At best, you can expect only 1-2 days knockdown kill of RSBs with pyrethroids. However, Tenchu 20SG has both contact and systemic activity which provide 7-10 days residual control based on field observations and experimental data. Sample as many places in a field as possible, time and effort permitting. For instance, if a field is rectangular, sample near the middle of each side (= 4 sample sites) of the field. Also, sample areas adjacent to sorghum fields or pastures where alternate host grasses are abundant. By doing this, aerial applications can possibly target only those areas of the field needing treatment. Some farmers "strip treat" fields for RSB (spray alternate swaths) using Tenchu 20SG which is systemic and has contact and residual activity. However, research data are not presently available to support this practice.

Do not compromise disease control with RSB control! Tank-mixing a pyrethroid with a fungicide applied mid-season is not recommended. RSBs do not enter rice fields until panicles emerge from the boot. Farmers are tempted to delay application of the fungicide in hopes of obtaining preventive control of RSB while maintaining good disease control. It is imperative to properly time fungicide applications, no later than 50-75% heading for sheath blight and blast control which can be too early for RSB insecticidal applications. In addition, needless application

of insecticides encourages resistance development.

Treatment decisions may be complicated by uneven stands. RSBs prefer developing grain. In fields where much of the rice has matured, more RSBs will be found on less mature panicles. Populations usually are higher around field margins and in weedy areas. Sampling these areas may cause artificially high estimates of RSB populations in the field. Unless spot treatments are feasible, decisions are best made using average sample estimates, as these are representative of the population across the entire field. Try to avoid applying insecticides to wet foliage or when rain may occur before the product has dried. Also, apply insecticides during early morning or late evening when bees are not foraging in rice fields. The objective of managing RSBs should be to maintain populations at or below threshold levels; do not expect to completely-eliminate RSB activity.

Cultural and Natural Control - Some cultural and natural control of RSB can be beneficial. Mowing field roads and controlling grassy weeds in rice paddies can reduce the abundance of alternate hosts. Planting levees with rice which competes with grassy weed growth can be helpful. Producing a uniform, vigorous stand of rice can minimize the period from heading to harvest. Also, planting early results in an earlier harvested crop which often can escape higher densities of RSB which can occur later in the year. Harvesting at the proper grain moisture level can reduce RSB damage, while delaying harvest simply allows more time for RSBs to damage the crop. Relative to natural control agents, spiders are excellent predators of RSBs and the wasp *Telenomus podisi* is an effective egg parasite of the RSB. In addition, *Beskia aelops* is a fly parasite that attacks later stages of the RSB. However, insecticides remain the first line of defense.

Stalk Borers

Texas rice is attacked by three species of stalk borers—the sugarcane borer*, Diatraea saccharalis*; the rice stalk borer, *Chilo plejadellus*; and the Mexican rice borer (MRB), *Eoreuma loftini,* all of which are introduced species. The MRB was first detected in a Texas rice field in a pheromone trap in Calhoun County in 1988. Studies before 2004 using pheromone traps detected MRBs in all rice-producing counties south and west of Houston. In 2004 they were detected in Chambers and Liberty counties. In 2005, they were detected in Jefferson County. So, this insect is moving roughly 15 miles eastward per year. Stalk borers appears to be more abundant in Calhoun, Colorado, Jackson, Matagorda, and Wharton counties, than in other counties of the Texas Rice Belt. The MRB has become the most abundant stem borer in the Texas Rice Belt. Now virtually all stem borers found infesting Texas rice are MRBs. In the fall of 2008, MRB moths were detected for the first time in Louisiana. This species has continued to spread in Southwest Louisiana and has been detected as far east as Florida. Larvae of MRB can be easily identified by the dark stripes on their abdomens (Fig. 13q). Each abdominal segment has two stripes on each side of the dorsal mid-line. These stripes are not continuous and look like two sets of equal signs (=) on the top of each abdominal segment. Larvae of the sugarcane borer have a dark head capsule and sclerotized plates (dark hard disks) with dark bristles emerging from them (Fig. 13r). The plates are scattered on the abdomens of the larvae. The least



Fig. 13q. Mexican rice borer larva**.**

abundant stem borer is the rice stalk borer whose larvae possess wavy continuous dark lines on their abdomens.



Fig. 13r. Sugarcane borer larva.

All three species lay eggs on rice foliage. The MRB moth prefers to lay on dead and dying leaves upon hatching, the larvae move to the protected areas between the leaf sheaths and culms. The second and third instar larvae typically bore into the culms and feed causing damage to vascular tissue, which causes deadhearts and whiteheads (Fig. 13s). Deadhearts are tillers that do not produce panicles due to early stem borer feeding. Whiteheads are blanked panicles that are white or gray and are easily observed in the field.



Fig. 13s. Stem borer lesion on rice culm.

Occasionally, larvae will feed on developing panicles within boots, causing partial blanking of panicles. Also, small MRB larvae can bore into internodes just below the panicles, which can result in a whitehead (Fig. 13t). Pupation occurs within damaged culms followed by emergence of adult moths. In general, all conventional rice varieties are susceptible to stalk borers. Late plantings are associated with more severe stalk borer damage.

Lowering cutting height of the main crop can reduce stalk borer damage in the ratoon crop. Borer populations may be reduced by low winter temperatures, heavy pasturing of stubble, fall plowing, or flooding fields during the winter. Ratoon rice is very susceptible to stalk borer damage.



Fig. 13t. Whiteheads caused by stem borers.

Lv et al. (2008) from a three-year field experiment, concluded *"Rice yield was not reduced with up to 23% injured"* leaves "*and up to 10% injured stems at the third tiller stage, 42% injured tillers and 17% injured stems at panicle differentiation, and 28% injured" leaves "and 14% injured stems at heading"*. This research shows *"rice can tolerate and/or compensate for a level of stem borer injury previously considered to be economically damaging"*. However, rice grown in southern counties of the Texas Rice Belt often experience very high stalk borer densities that will greatly reduce yields if not suppressed. Farmers in these counties may want to consider preventive treatments of labeled insecticides as listed and described in Table 13j. Data consistently show Dermacor X-100 seed treatment controls stem borers in both the main and ratoon crops.

Table 13j. Insecticides for stalk borer control.

Active ingredient/product	Rate per acre		Timing of applications
	Active ingredient	Product	
chlorantraniliprole Dermacor® X-100	See Table 16a		Apply to dry seed.
gamma-cyhalothrin DECLARE®	0.015–0.02 lb	1.54–2.05 fl oz	In areas with historically high populations of stalk borers and damage, apply at 1- to 2-inch panicle followed by a second application at late boot/early heading. Two applications are more effective than one.
lambda-cyhalothrin Karate® Z	0.03–0.04 lb	1.92–2.56 fl oz	
zeta-cypermethrin Mustang Maxx	0.020–0.025	3.2–4.0 fl oz	

For additional information on these products, read the labels or contact Dr. Lina Bernaola with Texas A&M AgriLife Research at lina.bernaola@ag.tamu.edu.

Leafhoppers

The blackfaced leafhopper, *Graminella nigrifrons*, is commonly found in rice, but is not usually abundant. Localized high populations have occurred in Brazoria Co. Infested foliage becomes discolored and yield and quality can be lowered. High populations can produce copious quantities of honeydew, a sweet excretion produced by feeding of the leafhopper. A microorganism, sooty mold fungus, grows on this honeydew causing foliage to turn black and sticky. A treatment threshold level has not been developed for this pest. However, several products have been evaluated for control. Of the insecticides registered for use on rice, carbaryl applied at 1.0 lb active ingredient per acre has provided good suppression.

Warrior II (lambda-cyhalothrin) and Mustang Maxx (zeta-cypermethrin) are labeled at 0.025 to 0.04 and 0.02 to 0.025, lb active ingredient per acre respectively. CruiserMaxx Rice, NipsIt INSIDE and Belay at the rates labeled for RWW in Table 13c, are reported to have activity against leafhoppers.

Rice Seed Midges

The larvae of these insects (Order Diptera, Family Chironomidae, Genera *Tanytarsus* and *Chironomus*) are aquatic and can be very abundant in rice fields. The adults are small, gnat-like flies that typically form inverted pyramidal mating swarms in the spring over stagnant or slow-moving water. Female flies lay eggs in ribbons on the water surface. The larvae hatch and move downward to the flooded substrate where they build protective "tubes" of silk, detritus, and mud. These brown, wavy "tubes" are easily observed on the mud surface of rice paddies. Occasionally, the larvae will exit the tubes and swim to the surface in a whiplike fashion, similar to that of mosquito larvae. Midge larvae can damage water-seeded (pinpoint or continuous flood) rice by feeding on the sprouts of submerged germinating rice seeds. Damage can retard seedling growth

or kill seedlings; however, the window of vulnerability to midge attack is rather narrow (from seeding to when seedlings are about 3 inches long).

Control rice seed midge problems by dry seeding, then employing a delayed flood, or by draining water-seeded paddies soon after planting. Thus, a pinpoint flood should reduce the potential for rice seed midge damage relative to a continuous flood. For water-seeded rice, reduce rice seed midge problems by increasing the seeding rate and planting sprouted seed immediately after flooding.

Aphids

Several species of aphids feed on rice in Southeast Texas. Aphids are small, soft-bodied insects with piercing-sucking mouthparts. This allows the insects to suck out plant juices. The nymphs do not have wings but look much like the adults. Adults have 2 pairs of wings and are quite mobile. They can spread from plant to plant by walking or field to field by flying or by being carried by the wind. Most species are parthenogenetic which means females can produce offspring without having to mate with males. Some aphids give birth to living young and others lay eggs. Regardless of method of reproduction, aphid densities can increase very quickly, and they are good colonizers/invaders of previously unoccupied areas. Aphids will develop wings when host food or local environmental conditions are not favorable. This allows them to move from unfavorable to favorable environments.

Aphids are generally slow moving, so they are easy to spot on rice foliage. Also, they are usually found in groups instead of singly. A group of aphids generally is derived from a single adult female. Aphids can vary greatly in morphology, depending on the species, but all aphids possess 2 cornicles, which look like automobile "exhaust pipes". These structures are near the end of the abdomen and are easily visible. The shape, color and length of the cornicles can help identify a given species. The function of cornicles is to provide an outlet for defensive secretions and pheromones. They are not involved in releasing honeydew which is the purview of the anus. Honeydew is a sugary, glistening substance which serves as a food source for sooty mold fungus. When aphid populations reach high densities, abundant release of honeydew can lead to a black coating of this fungus on foliage which interferes with photosynthesis. Presence of honeydew and sooty mold fungus can indicate high populations of aphids. So, if you see foliage with sweet, glistening honeydew and/or a black coating of sooty mold fungus, rest assured you have an aphid infestation (Fig. 13u) or a planthopper infestation. Planthopper infestations which will be addressed in a later section of this chapter.



Fig. 13u. Aphid damage to rice on edge of in-field drain ditch.



Fig. 13v. Bird-cherry oat aphid (photo courtesy of Iowa State University).

Probably the most common aphid attacking rice in Southeast Texas is the bird cherry-oat aphid, *Rhopalosiphum padi* (Fig. 13v). Adults are about 1/16 inch long, variable in color but mainly blue/reddish green with slender dark cornicles and dark legs. They can attack young rice

causing yellow discoloration which can lead to stunting. Frequently, infestations will be found on rice growing from soil thrown up on the sides of shallow ditches made by farmers to help drain paddies before the permanent flood is applied. This localized damage can be alarming, but seldom is it widespread enough to cause unacceptable yield loss.

A more problematic aphid is the yellow sugarcane aphid, *Sipha flava*, which has been observed only attacking seedling rice (Fig. 13w). Adults are about 1/16 inch long and lemon-yellow colored which makes them easy to identify. Their cornicles and legs are short, and the body possesses hairs and black spots arranged in regular rows. This aphid introduces a toxin into the plant which causes stunting, rosetting and yellow-reddening discoloration of foliage. Prolonged feeding can cause stand loss.



Fig. 13w. Yellow sugarcane aphid (photo courtesy of P. Porter).

Another aphid observed only attacking levee rice is the rice root aphid, *Rhopalosiphum abdominalis*. This aphid is brown purplish, somewhat round, and relatively small. They have been observed feeding above and below ground on rice growing on levees where the soil is not water saturated (Fig. 13x). At the time of observation, plants were past tillering and damage symptoms were not obvious.



Fig. 13x. Rice root aphid (photo courtesy of W. Cranshaw).

The English grain aphid, *Sitobion avenae*, is yellow green with long, dark antennae and cornicles (Fig. 13y). In the past, this species has only been observed attacking rice panicles in the greenhouse. However, in 2020, it was found damaging maturing main crop rice in Wharton County.

There are many natural enemies of aphids such as lady bird beetles, lacewings, syrphid fly larvae, parasitoids, and diseases. Also, timely rains can wash aphids off plants. An excellent cultural control, which is frequently employed on seedling/young rice, is to flush/flood or increase water depth in paddies. Finally, several insecticides, including selected seed treatments, provide control. Early infestations relative to rice growth are the most damaging, so scouting fields from emergence to tillering is the key to managing aphids.



Fig. 13y. English grain aphid (photo courtesy of J. Obermeyer).

When searching for aphids, remember to inspect the collar region (the junction of the leaf blade and sheath) of rice plants. Aphids are often found here because the relative humidity is high, the plant tissue is tender, and concealment from natural enemies is possible. No treatment thresholds are currently available for aphids attacking rice; but, if stands are threatened or the rice is yellow/reddish/stunted and aphids are present, treat the rice with an approved insecticide.

Four practices discourage aphid populations and damage:

- Flushing or flooding, which drowns the insects and forces them to move up the plant, where

they are more vulnerable to natural control

- Controlling weeds, which prevents aphids from building up on alternate hosts
- Establishing a healthy, uniform stand of rice
- Reducing early-season stress caused by inadequate soil moisture, herbicide injury, nutrient imbalances and damage from other pest insects and diseases

The following insecticides perform well against aphids attacking rice: the seed treatments CruiserMaxx Rice and NipsIt INSIDE at the rates recommended for RWW, Warrior II at 0.025-0.04, Mustang Maxx at 0.02-0.025, and Belay at 0.075 lb active ingredient per acre.

South American Rice Miner *(Hydrellia wirthi)*

During the past several years, the South American rice miner and its associated injury have been observed in Texas and Louisiana rice (Fig. 13z-aa). The adult of this insect is a small, gray fly that lays eggs singly on rice foliage. The eggs hatch, and larvae rasp and feed on developing foliage before the leaves unfurl. The larvae feed within leaves, resulting in mines and lesions. Once the leaves unfurl, it is easy to see the signs of damage: relatively wide, white, elongated mines or lesions parallel to the leaf venation, similar to but wider than adult RWW feeding scars. This often causes the distal portion of leaves to break off or "hang by a thread," giving the affected rice plants a ragged, tattered appearance. The larvae are small, white, and legless. Pupae, which are brown, also can be found inside the lesions or mines.



Fig. 13z. Rice leaf miner adult.



Fig. 13aa. South American rice miner damage.

Generally, injury occurs when rice is tillering. However, in Louisiana in 2004, a rice field planted late was severely damaged soon after emergence. In Texas, economic damage has not been observed, but be aware of this pest and report suspected injury to the Beaumont Center.

Channeled Apple Snail *(Pomacea canaliculata)*

Channeled apple snails are invertebrates that were found in or near rice fields in Brazoria, Galveston, Fort Bend, Harris, Waller, and Chambers Cos. These snails most likely were introduced from South America to Texas via the aquarium pet trade. They have become serious pests of rice in South America and Southeast Asia where they were originally imported as a food source. The adults are large (shell height about 3 to 4 inches), globular and banded with brown, black, and yellowish-tan patterns of coloration. Although the snails feed on many types of vegetation, they prefer to feed on succulent, submerged plants. This pest has been observed in Texas rice fields feeding on alligator weed and duck salad.



Fig. 13ab. Channeled apple snails and pink egg mass (photo courtesy of G. Bradshaw).

The egg masses are cylindrical, pink or red, and typically observed above the waterline on rice plants, weeds, or human-made structures. To date, snail damage to rice in Texas has not been documented, possibly because of the practice of delayed flooding in Texas. However, in 2016, these snails were observed burrowing into levees causing loss of flood in paddies. Also, they have been reported in Louisiana as pests of crayfish farms because they clog up crayfish traps.

Panicle Rice Mite *(Steneotarsonemus spinki)* and Spider Mites (tetranychid spp.)



Fig. 13ac. Panicle rice mites (photo courtesy of N. Hummel).

The panicle rice mite, *Steneotarsonemus spinki*, is a serious pest of rice in Latin America, the Caribbean, and parts of Asia. It is an introduced pest of rice in Texas where it can be found in very low, non-damaging numbers in commercial rice fields. However, it has been found in high, damaging densities attacking rice in Texas greenhouses where hot, dry conditions prevail which are conducive to mite population build-up. This species is extremely small and nearly invisible without a magnifying lens (Fig. 13ac) The mites are somewhat clear to yellowish in color and elongate. The male possesses 2 characteristic clasper-like appendages protruding from the end of its body. The mouthparts pierce rice tissue allowing for the uptake of plant juices. Damage to foliage causes bronzing and drying. The panicle rice mite also can transmit a bacterium (*Burkholderia glumae*) that can cause bacterial panicle blight leading to severe yield loss.



Fig. 13ad. Spider mite damage (photo courtesy of LSU).

In 2007, USDA-APHIS found the panicle rice mite in greenhouses near Alvin, TX and threatened a quarantine on rice grown in Texas. However, inspections of commercial rice revealed very low populations and little or no damage, so a threatened quarantine was not imposed. At the same time, greenhouses at the Beaumont Center were inspected regularly by USDA-APHIS officials. Eventually, inspections were curtailed after eradication of the mite in these greenhouses.

Spider mites are also very small but relatively speaking they are much larger than panicle rice mite. Spider mites feed on leaves causing discoloration (Fig. 13ad). They can also feed upon and damage panicles grain and only rarely cause yield loss if infestations are particularly severe.

Rice Delphacid/Planthopper *(Tagosodes orizicolus)*

The rice delphacid or planthopper is native to Latin America and the Caribbean. It recently was observed in high numbers attacking ratoon rice foliage south and west of Houston in 2015, and 2018 through 2022. Infestations was probably present in 2016 and 2017, but populations were too low for easy detection. As an adult, this insect looks like a leafhopper and is about ¼ inch long and dark in color. Planthoppers have a large spine on their hind legs while leafhoppers have 1 or 2 rows of small spines on their hind legs. Nymphs (immatures) is lighter in color than the adults and has 2 characteristic brown stripes on each side of the abdomen (Fig. 13ae-13ag). The insect has piercing-sucking mouthparts which are used to suck out the juices of the rice plant. If populations are high enough, this feeding can result in "hopperburn" causing rice to turn yellow/brown and prematurely die. In addition, the insect excretes "honeydew" which serves as a food for black sooty mold fungus (Fig 13ah-13ai). Presence of sooty mold fungus on foliage indicates an abundance of rice planthoppers (or leafhoppers). The insect also can take up the rice hoja blanca virus (RHBV) from infected rice plants and transmit the virus to healthy rice plants causing hoja blanca disease. Symptoms of hoja blanca disease include stunting, general yellowing of the rice plant, yellow stripes running parallel to leaf veins and failure to produce seed. The virus can exist and multiply in the insect for a long period of time and can be transmitted to the offspring via the egg. The virus eventually becomes detrimental to the insect resulting in population crashes; thus,



Fig. 13ae. Adult rice planthopper (photo courtesy of W. Nanson).



Fig. 13af. Rice planthopper nymph.



Fig. 13ag. Black sooty mold fungus on rice ratoon stubble caused by rice planthopper honeydew (photo courtesy of J. Martin).



Fig. 12ah. Hopperburn in ratoon rice.



Fig. 13ai. Severe hopperburn in ratoon rice.

disease epidemics in Latin America are cyclical. However, molecular analysis of specimens collected in 2015 and 2020 in Texas revealed they were non-viruliferous.

In its native region, the best management tool is the use of resistant/tolerant rice varieties, although some farmers apply insecticides. Limited observations in Texas in 2015 and 2018 did not detect varietal differences in susceptibility to this insect.

Seed of selected southern U.S. rice varieties will be shipped to the International Center of Tropical Agriculture (CIAT) for evaluation for resistance/tolerance to the rice planthopper and hoja blanca disease (Fig. 13hj-13ak).

Insecticide evaluations continue. See the prior discussion under "Regulatory Actions" regarding Endigo ZC and Tenchu 20SG. Both insecticides control this exotic insect. Use rates are 4.5-6.0 fl oz/acre for Endigo ZC and 7.5-10.5 oz/acre for Tenchu 20SG. However, information is not available on treatment thresholds.



Fig. 13aj. Hoja blanca disease in CIAT screening nursery.



Fig. 13ak. Hoja blanca disease symptoms on rice foliage.

Other Arthropod Pests

Many other insects have been reported to be rice pests, but they are of undetermined or minor importance. These included the following

Coleoptera - Flea beetles, Grape colaspis, *Colaspis brunnea,* Cattail billbug, Sugarcane beetle, *Euetheola rugiceps*

Lepidoptera - Fiery skipper, *Hylephila phyleus*; Least skipper, *Ancyloxypha numitor*; Ocola skipper, *Ponoquina ocola*

Diptera - Rice leaf miner, *Hydrellia griseola*

Hemiptera - *Paromius longulus*; *Leptocorixa tipuloides*; Sharpshooter, *Draeculacephala portola*

Thysanoptera - Thrips, species undetermined

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Vertebrate Management

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Blackbirds, primarily red-winged blackbirds, are pests of rice during the planting season, the seedling stage, and during grain ripening. The birds consume seed and seedlings on and under the soil which can result in poor plant stands, and in some cases, fields must be replanted. Reseeding is expensive and delays crop development which may reduce yields and quality and hinder harvesting operations. Also, harvesting the main crop late can make ratoon cropping impractical and increase the chances of blackbird damage on the ripening main and ratoon crops. Blackbirds also damage the ripening crop by "pinching" grain in the milk stage with the beak to force the milky contents into the mouth, hulling grain in the dough stage and consuming the contents and breaking panicles by perching and feeding. This type of damage is insignificant in the ripening main crop, according to the results of a study in Matagorda County by Texas A&M AgriLife Research and Texas A&M AgriLife Extension Service. However, damage to the ripening ratoon crop was severe, particularly along field margins. Yield losses ranged from about 4 to 15%, even in fields patrolled using firearms, with the cost of control as high as $46 per acre. Some producers do not ratoon crop, simply because of potential bird problems. Producers have had to abandon parts of fields hit hard by birds and/or have had to harvest earlier than is optimal to save the ratoon crop from bird attacks. For both damage periods (planting and heading to harvest), fields near wetlands or roosts usually suffered more damage. Unfortunately, no easy solution is available, although a combination of control tactics can reduce the problem.

To help control blackbirds on emerging rice:

- Delay planting until large flocks of birds move north, and try not to plant when your field is the only one in the area with seeds and seedlings available for the birds
- Increase the seeding rate if you usually experience bird problems at planting, and cover the seed to make it more difficult for the birds to find
- Patrol the fields early and consistently use firearms and scare devices. This is probably the most effective tactic. Laborers can be hired to perform this tedious but important job. If possible, make sure all margins of the field are accessible for patrol. Start patrolling immediately after planting to scare away "scout" birds. Birds are more difficult to move once they are established in a field. Most feeding occurs during the early morning and late afternoon. However, always patrol the fields if birds are present.
- If possible, destroy roosts and loafing sites on the margins of fields

DRC 1339, a blackbird toxicant formulated as a bait, can be used to kill blackbirds that threaten rice. It can be applied only by authorized governmental personnel. This baiting program is only effective when conducted in the winter and is designed to provide relief from localized birds prior to planting.

In 2015, AV-1011 was given "conditional" approval by USEPA for use as a rice seed treatment to repel blackbirds from consuming sprouting rice. Currently, AV-1011(active ingredient anthraquinone) has a full federal Section 3 label and the recommended rate is 18.6 fl oz/ cwt seed, so the lower the seeding rate, the lower the cost on a per acre basis. Many Texas rice farmers are using AV-1011 and are pleased with the results.

To help control blackbirds on ripening rice:

Because production inputs have already been invested in the crop, it is imperative that you protect the ripening rice.

- Plant an early-maturing variety so that the harvest occurs before the flocks increase to damaging numbers. Late plantings increase the chance of bird damage to the ratoon crop.
- Manage the habitat, and patrol early and consistently. These are the most important control measures.
- Harvest as soon as grain moisture is appropriate. The longer rice remains in the field, the greater the chance for bird damage.

In the fall of 2002, the USEPA approved the use of Bird Shield in rice to limit feeding by blackbirds. The active ingredient in Bird Shield is methyl anthranilate, a bird repellent. Bird Shield can be applied to rice seed at planting or to heading rice. Residue data were collected in Texas to help register the product, but field efficacy data are unavailable.

The economic losses of feral hog damage to agriculture in Texas are estimated at more than $52 million annually. It is also estimated that Texas has a feral hog population of more than 2.5 million which is the largest in the U.S. The feral hog population in the Texas Rice Belt is probably as large as any other area in the state and feral hog damage in rice can be severe. Feral hogs are prolific breeders. Sows are sexually mature at 6 months of age, but usually don't breed until 8 to 10 months of age. They may have more than 1 litter per year. The gestation period for feral hogs is 115 days and litter sizes range from 4 to 12 piglets; but as in domestic animals, litter size depends upon the sow's age, nutritional condition, and the time of year she breeds. Young ones may be born at any time of year.

Feral hogs impact rice farming operations through their feeding and wallowing activity. They feed on maturing rice crops, cause damage to rice field levees, and interfere with water management. During dry periods, hogs may be attracted to rice fields due to the availability of water that the fields provide for wallows and resting areas. Occasionally, feral hogs may remain in or near a rice field for extended periods. They may also travel a considerable distance to and from a rice field daily. Feral hog damage in rice farming operations is not necessarily related to the number of animals that are active in a particular location. Extensive damage can be the result of the activity of one sounder, or a single large boar, or it can be the result of several sounders. Careful examination of feral hog tracks, trails, wallows, rubs and other signs of feral hog activity can reveal the approximate number and size of the feral hogs active in an area and travel routes that feral hogs use when moving to and from rice fields.

A careful survey of each feral hog damage location is necessary to determine the best course of action to resolve the problem. Various of damage management methods and techniques are used to resolve feral hog damage problems. Legal methods for reducing feral hog damage include trapping with cage traps, snaring, shooting, use of dogs to hunt and harass feral hogs, and aerial hunting. There are many effective techniques for applying these various methods, but development of the expertise and skills required to effectively use these methods may require considerable time, effort, practice, and monetary cost.

Many publications are available through USDA/APHIS/Texas Wildlife Services, Texas A&M AgriLife Extension Service and other sources that provide details of the various methods and techniques currently used to manage feral hog damage to agriculture in Texas. Some of these publications may be viewed and printed at the following web sites: Texas Wildlife Services: http://agrilife.org/txwildlifeservices/, USDA/APHIS/Wildlife Services/Feral Swine: https://www.aphis.usda.gov/aphis/resources/pests-diseases/feral-swine, Texas A&M AgriLife Extension: http://feralhogs.tamu.edu/.

POST-HARVEST GRAIN MANAGEMENT

Post-Harvest Grain Management

Y. Yang, L. T. Wilson, and F. H. Arthur

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Once a rice crop is harvested, it needs to be stored for a period before it can be marketed or used as feed or seed. The length of time rice grain can be safely stored depends on its condition at harvest and the type of storage facility used. Grain stored at lower temperatures and moisture contents can be kept for longer periods before quality deteriorates. Grain quality and storage duration are affected by the presence and buildup of insects, mites, molds, and fungi, which are all affected by grain temperature and grain moisture content.

Although the biggest threats to stored rice are the rice weevil (Fig. 15a) and the lesser grain borer (Fig. 15b), excessive moisture and temperature variations can also affect grain quality. Monitoring stored grain depends on bin managers, requiring diligence and near constant oversight.

The rice weevil and lesser grain borer are primary feeders that complete their development inside kernels. Because infestations are hidden, they are often undetected until their populations reach damaging levels. An important component of any grain bin management program is using low-volume ambient air (aeration) to cool the grain mass to the level (60°F) that will reduce insect population development.



Fig. 15a. Adult rice weevil (photo by Joseph Berger, from Bugwood.org).



Fig. 15b. Adult lesser grain borer (photo from grdc.com.au).

Aeration is the process of ventilating stored grain at low airflow rates to maintain a uniform grain temperature throughout the bin. Aeration prevents moisture accumulation at the top layers of the bin because of natural convection. Pressure aeration pushes ambient air from the bottom of the bin upwards while suction aeration pulls air from the top downward by reversing the fans (Schafer 2011) (Fig. 15c). Research conducted in Arkansas shows pressure aeration cools grain faster, significantly reducing pest populations in wheat. Aeration may be used with field-dried grain or with grain that is harvested damp, then dried and cooled in a heated air dryer. In both

cases, the grain may vary in temperature and moisture content, and it may be too warm to store safely.

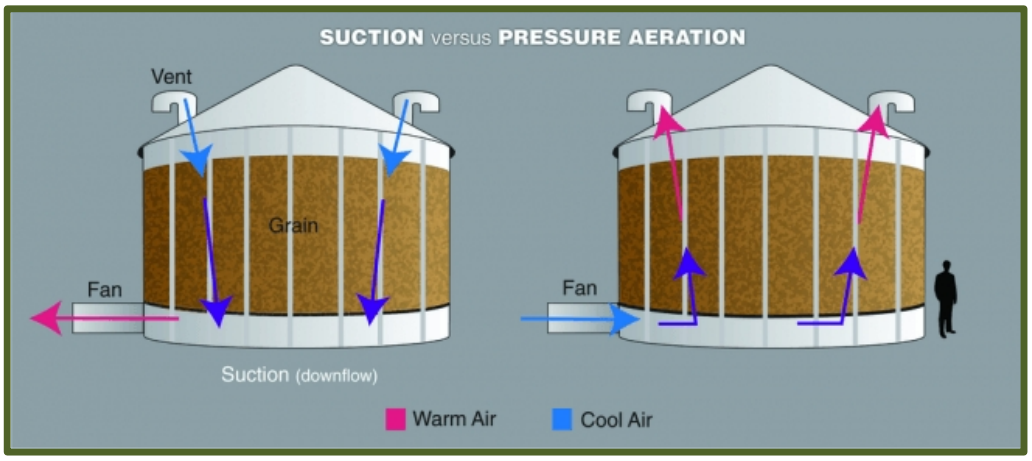


Fig. 15c. Pressure versus suction aeration (photo from Schafer 2011: http://www.feedandgrain.com/magazine/suction-aeration-a-better-way-to-manage-pests).

Variation in grain temperature is also caused by changes in the outside air temperature after the grain is stored. The amount of air required to change the temperature of the grain may not affect grain moisture content because of the low airflow rates used in aeration. Although bin aeration is not intended to be a grain drying system and should not be considered as such, some drying can occur when the weather is very dry, and the fan is run for a long time.

Fan operation should be controlled by maintaining a difference of less than 10˚F between grain temperature and the average outside air temperature. Grain is cooled in the fall, kept at low temperatures in the winter, and warmed in the spring. Improper aeration leads to mold development. Early signs of mold growth can be detected by smelling the first air that is exhausted from the storage after fans are turned on.

Generally, fans can be operated when the outside relative humidity ranges from 55 to 70%. If the airflow rates are high, humidity below a recommended range can over dry the grain, while humidity above the range may raise the grain moisture to unsafe levels. These levels are determined by the equilibrium moisture content (EMC) of the grain, a point at which the grain is neither gaining nor losing moisture. If the relative humidity is constant, a rise in air temperature will lower the EMC. Likewise, if the temperature is constant, a rise in relative humidity will raise the EMC. At 77°F and 75% relative humidity, the EMC for rough rice, brown rice, and milled rice is 11.89, 13.01, and 13.04, respectively. These numbers may change slightly with different rice varieties and grain types, as lipid levels in the bran affect the EMC.

Most moisture meters read the surface moisture of the grain. Rice just coming out of a dryer may read 13%, but afterward that reading could go up by 1 or more percentage points. This is known as the "rebound effect," and should be considered as grain goes into storage. Fissuring occurs when the moisture gradient between the kernel and the air is high, and moisture rapidly enters the grain.

During fan operation, the air temperature should be cooler than the grain in the fall and warmer than the grain in late spring. Some aeration controllers automatically start and stop fans based on grain and air temperatures; some also control based on air humidity. The minimum airflow rate for grain aeration is 0.5 to 2.0 cubic feet per minute per bushel (CFM/Bu). Grain with low initial moisture content requires a lower airflow rate. Larger fans will speed up the cooling process as more air is moved through the grain.

Grain in storage is subject to moisture migration caused by differences in grain temperature. This is particularly true for grains stored in metal bins. In late fall and early winter, stored grain tends to be warmer than the outside air. Warm air rises slowly out of the center grain. When this air contacts the cold grain on the top of the bin, it cools, increases in relative humidity, and causes the top grain to gain moisture, which can lead to rapid spoilage. A common symptom of moisture migration is crusting on the surface of stored grain. Significant migration of moisture can occur in grain at moisture contents as low as 12% wet weight basis if the grain is placed into storage at a high temperature and not cooled. Air and grain that are close to cold walls or floors also cool. Moisture migration is slowed by aeration, regularly forcing outside air through the grain to reduce the temperature difference between the grain and the outside. During the fall, aeration is used to cool the grain and maintain moisture uniformity. In the winter, aeration is needed just to maintain moisture uniformity.

Keep the grain temperature as low as possible during the spring to reduce insect damage. Insects become active when grain temperature rises above 65°F, and infestation and damage are likely when the grain temperatures are between 75 and 90°F, which is the optimum range for growth and development of stored-grain insects.

To summarize, good storage practices can prevent losses in grain quality by:

- Keeping the grain moisture content of grain below 12.5%, which corresponds to about 65% relative humidity
- Keeping the grain temperature within 10°F of the average monthly air temperature and below 60°F, for as long as possible during the year
- Designing and operating an aeration system to maintain uniform grain moisture and temperature
- Storing only well-cleaned grain. Fungi (mold) growth is minimal below 65% relative humidity and bacteria growth is minimal at even higher relative levels of humidity
- Reducing the occurrence of rapid shifts in temperature, thereby controlling grain fissuring
- Monitoring and reacting appropriately to any changes that may occur

Safe, long-term storage moisture for grain is based on grain dryness. Although grain can be stored above 12% moisture content, the risk of noticeable mold growth increases as moisture, storage time and grain temperature rise. During the storage, inspect the grain weekly. Test the discharge air for off-odors; any increase in temperature within the grain, and any increase in moisture generally indicate a problem.

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Web-Based Postharvest Grain Management

Y. Yang, L. T. Wilson, J. Wang, F. H. Arthur, and T. McKay

The Postharvest Grain Management program (*http://beaumont.tamu.edu/GrainManagement*) is a web-based grain management tool (Fig. 16a) that allows users to develop strategies to optimize the control of rice weevil, *Sitophilus oryzae* (L.), lesser grain borer, *Rhyzopertha dominica* (Fabricius), and red flour beetle, *Tribolium castaneum* Herbst, in rice storage bins and in rice mills. It provides an interactive web-based interface for users to customize storage and mill configurations and to evaluate the effectiveness of different pest control options (aeration, fumigation, sanitation, surface treatment, and monitoring).

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Fig. 16a. Main Page of the Post-Harvest Grain Management Program.

The tool was developed jointly by scientists from Texas A&M AgriLife Research, USDA-ARS Manhattan, Kansas, Arkansas State University, Oklahoma State University, Louisiana State University, University of Arkansas, and University of Missouri. The program is directly linked to a weather database that contains data for the six major rice-growing states (Arkansas, California, Louisiana, Mississippi, Missouri, and Texas) in the U.S. The weather database is updated automatically every day with data from several sources, mainly weather data from the National Oceanic and Atmospheric Administration (NOAA).

Major features. The Post-Harvest Grain Management Program has the following major features:

- Prediction of grain temperature and moisture dynamics in storage bins
- Prediction of grain temperature and moisture dynamics in rice mills
- Prediction of rice weevil, lesser grain borer and red flour beetle population dynamics
- Sensitivity analysis of different bin and mill configurations
- Sensitivity analysis of different pest configurations
- Ability to create, edit and run multiple bin and mill profiles
- Graphic display of results for aeration and pest dynamics
- Access to weather data for multiple stations and years
- Ability to add, view and edit user-specific weather data

Interface windows. The web interface (Fig. 16a) has three major panes:

- The left pane displays links to major program features *(About This Program, Login, New Account, Create Profile, View / Edit Profile, Run Profile, Results and Analysis, and Weather Data).* An additional feature (*Account Info*) is available for users who have an account with the system.
- The top banner pane displays links to information that is relevant to the Post-Harvest Grain Management program (Research Team, Display Unit, Calculators Etc., Knowledge Base, Resources, and *e*Tools)
- The main pane allows users to input, edit, and view configuration data or display simulation results

Farm or Mill Profile: A farm or mill profile is a set of conditions for an on-farm storage or a mill, including bin/mill and pest configurations, bin/mill management options, and weather data needed to forecast the dynamics of grain temperature and moisture, and pest population development.

Guest User: A guest user can use the Postharvest Grain Management Program without registering. However, the user will not be able to use some of the advanced features, cannot create multiple profiles, and cannot keep the settings and results for later access once the browser is closed.

Registered User: A registered user, by creating an account, can use all the features of the Postharvest Grain Management Program. Registered users can create multiple profiles and keep their settings and results for later access. They can also add their own weather data.

Create Profile: Create a new profile for an on-farm storage or a rice mill, including weather station selection, bin/mill and pest configurations, and pest control measures (Figs. 16b-d).

View / Edit Profile: View, edit, or delete existing profile(s)

Run Profile: Run one or multiple profiles

Results and Analysis: View, analyze, and download results for aeration and pest dynamics.

The *Aeration Dynamics* submenu displays the dynamics over time for grain temperature, grain moisture, relativity humidity, and fan power consumption (Fig. 16e).

The *Pest Dynamics* submenu displays dynamics and damage of rice weevil, grain borer, or red flour beetle over time (Fig. 16f-g).

The *Weather Data* menu gives users background information about weather data and options for adding user weather data and viewing weather data for different weather stations.

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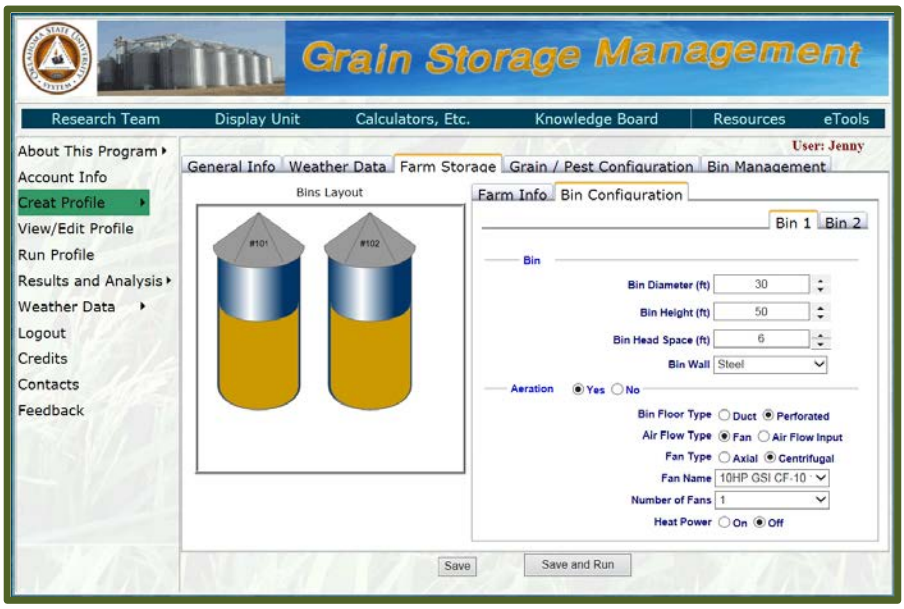


Fig. 16b. Create Profile – bin configuration.



Fig. 16c. Create Profile – grain configuration.

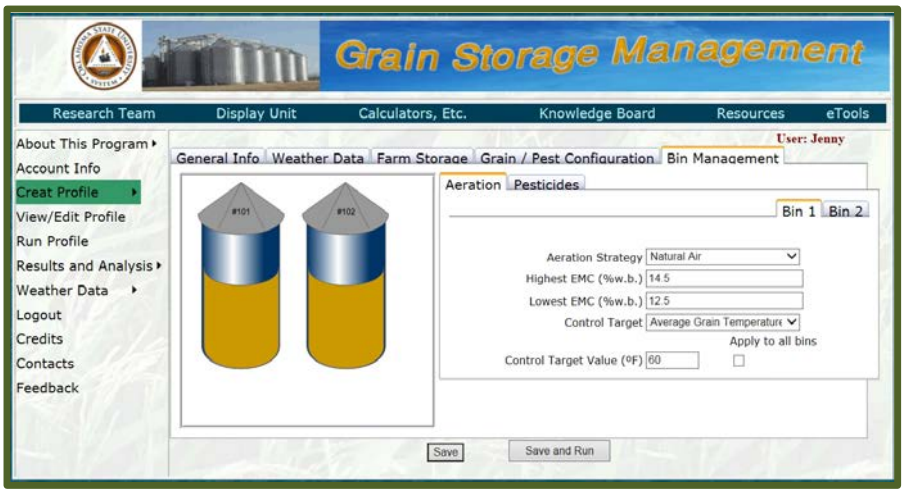


Fig. 16d. Create Profile – aeration configuration.

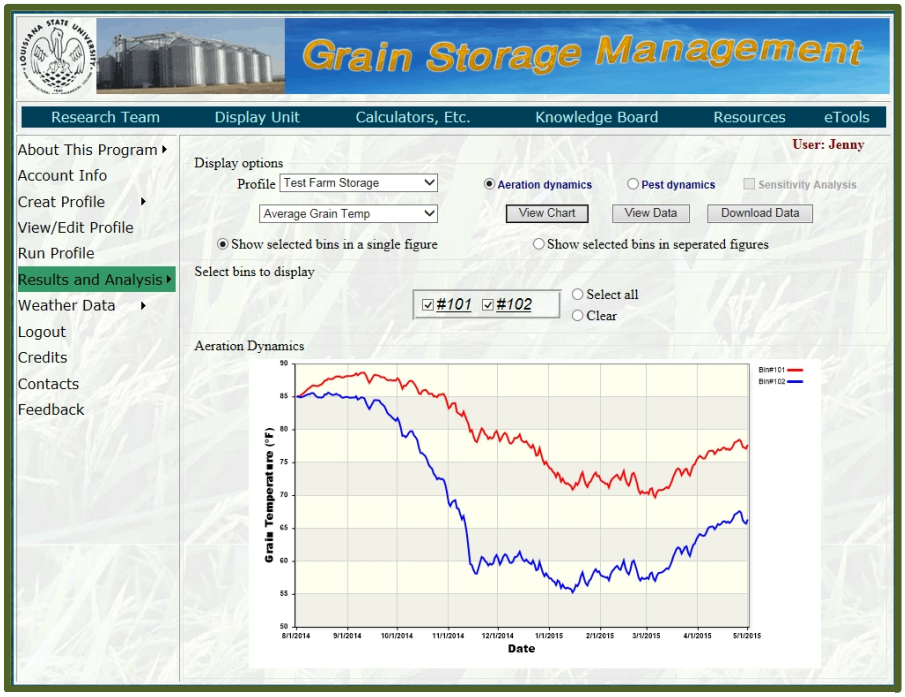


Fig. 16e. Simulated grain temperature with (blue line) and without (red line) aeration in rice storage bins in Eagle Lake, Texas.

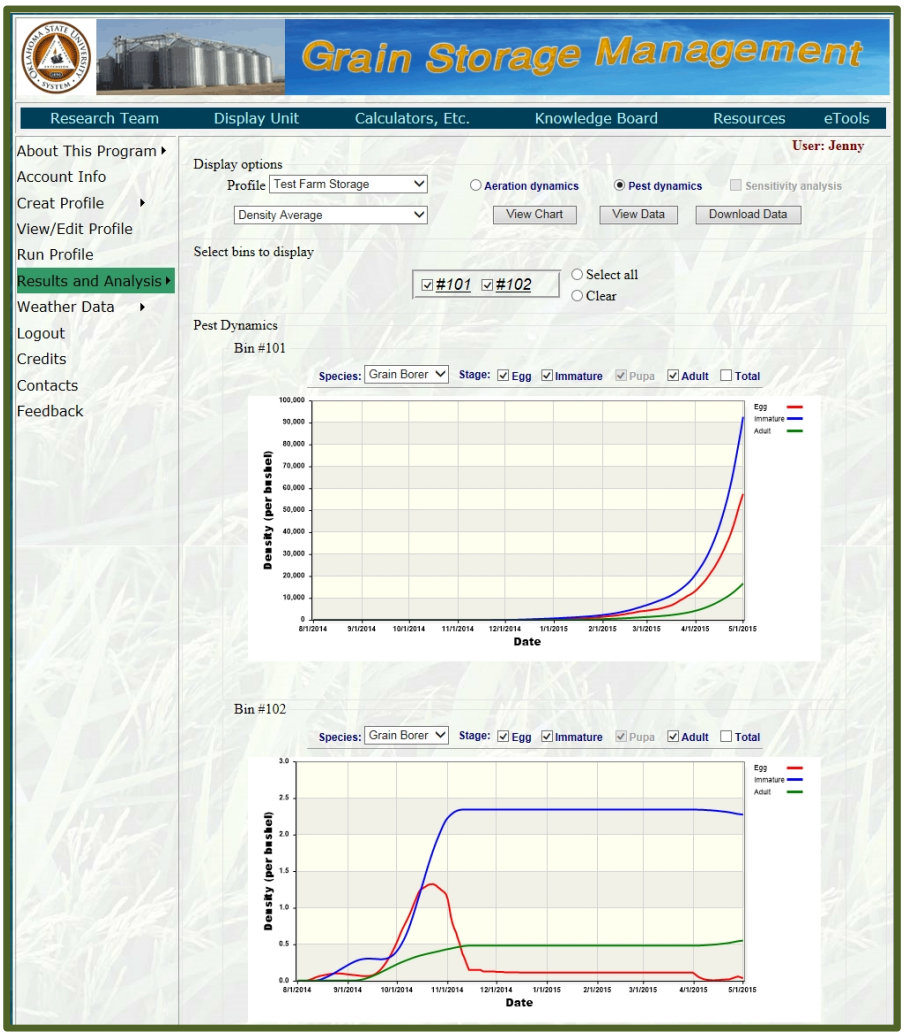


Fig. 16f. Simulated lesser grain borer population dynamics in rice storage bins with aeration (bottom) and without aeration (top).

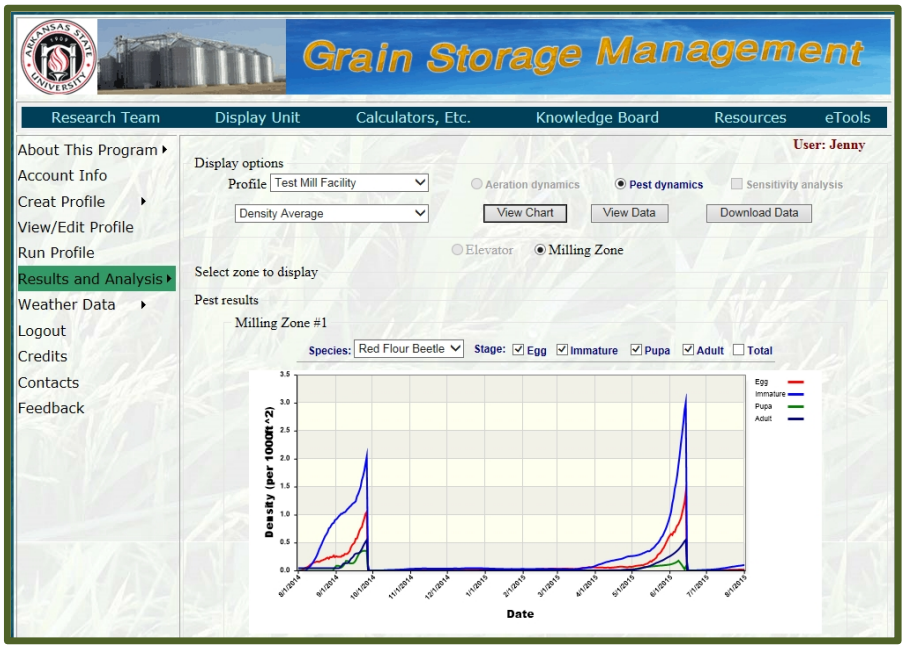


Fig. 16g. Simulated red flour beetle population dynamics with threshold-triggered fumigation (0.5 adults/1000 ft^2 and 95% fumigation mortality).

RICE PRODUCTION ECONOMICS

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Rice plantings in Texas have averaged 184,200 acres over the last five years (2018-2022), ranging from a low of 157,000 acres in 2019 to highs of 195,000 in 2018 and 2022. Drought and its impact on the availability of surface water for rice producers in the area west of Houston severely impacted the total planted acres of Texas rice in the previous decade. However, more favorable water situations in recent years have allowed planted acres to rebound to 10-year highs in 2018, and 2022. Producers again have an eye turned to drought this winter, as surface water allocations for irrigation could again be threatened without significant rainfall heading into the 2023 spring planting season. Marginal rice price increase and elevated costs of production were the story of 2022, with cost increases experienced in every major production cost category charted in Figure 17a. Nitrogen fertilizer and fuel led the increases, with year-over-year increases of 76 percent and 41 percent, respectively. Increases experienced in potash and phosphorous fertilizers were not far behind with a 31 percent annual increase for this expense category in 2022. Wages, repairs, seed, chemicals, and machinery all experienced year-over-year increases ranging from 6 percent to 16 percent. While producers are projected to experience an approximately 15 percent higher marketing year average (MYA) price for long grain rice, this figure is expected to return to a more typical level much sooner than input costs.



Fig. 17a. Actual and projected indices of prices paid by farmers and national average MYA price received by farmers for long grain rice.

Cost of Production Estimates for the 2023 Crop

The planning budgets shown in Tables 17a-b were developed primarily from input from Texas A&M AgriLife Extension Service specialists along with producers cooperating with the Agricultural and Food Policy Center (AFPC) to develop representative rice farms used in analyses for Congress. Rates of change for input prices were obtained from the Food and Agricultural Policy Research Institute in their 2022 August Baseline Update for U.S.

Agricultural Markets. These enterprise budgets are intended to project input prices and prices received for long-grain rice for the 2023 crop year. These budgets represent the cost structure for a hypothetical 450-acre rice operation on land that requires 18-20 levees per 100 acres. The budget scenario represents a moderately yielding, high input conventional tillage production system with moderate to heavy pest pressure. Main crop (1st crop) and ratoon (2nd crop) crop enterprises have been separated for the "Rice West of Houston" budget; all general and administrative costs, crop insurance, land, and vehicle charges are assigned to the main crop. The detailed budgets reflect surface water irrigation practices; however, it is important to note that groundwater irrigation systems using diesel, natural gas, and electric power units have significantly different costs and resulting net returns associated with each practice. For more information regarding costs associated with groundwater irrigation systems, please contact your local Texas A&M AgriLife Extension Service office or specialist.

Table 17a. Summary of projected costs and returns per acre; rice west of Houston (first crop); 450-acre farm; surface water, 2023.

REVENUE	**Quantity**	**Units**	**$/Unit**	**Total**
Rice 1st Crop Loan	70	CWT	$7.00	$490.00
Rice 1st Crop Premium	70	CWT	$7.00	$490.00
Total Revenue				$980.00
VARIABLE COSTS	**Quantity**	**Units**	**$/Unit**	**Total**
Production Costs				
Herbicide				
Clomazone	0.1	Gallon	$95.00	$9.50
Rice PostEmerge Herbicide 1	1	Acre	$20.29	$20.29
Rice PostEmerge Herbicide 2	7	Ounce	$2.14	$14.99
Seed				
Rice	0.9	CWT	$54.01	$48.61
Fertilizer				
17-21-14-4.3S`	0.141	Ton	$752.36	$106.08
33-0-0`	0.1	Ton	$861.41	$86.14
46-0-0`	0.075	Ton	$765.36	$57.40
Custom				
Base Fertilizer	1	Acre	$6.30	$6.30
Ground Application	1	Acre	$6.83	$6.83
Survey Levees	1	Acre	$6.21	$6.21
Pre-Flood Application	1	Acre	$12.28	$12.28
Aerial Application	4.5	Acre	$8.07	$36.33
Top Dress	1	Acre	$9.31	$9.31
Rice Hauling	80.5	CWT	$0.43	$35.00
Rice Drying	80.5	CWT	$1.31	$105.39
Miscellaneous				
G&A Overhead	1	Acre	$10.87	$10.87

Pickup Milage Charge - Rice	1	Acre	$19.39	$19.39
Base Water Charge	1	Acre	$66.91	$66.91
Butt Up Field	1	Acre	$4.06	$4.06
Plastic	1	Acre	$2.52	$2.52
Pipe	1	Acre	$3.02	$3.02
Commission	70	CWT	$0.08	$5.60
Check Off	70	CWT	$0.08	$5.60
Rice Storage	70	CWT	$0.32	$22.40
Crop Insurance -Rice Enterprise	1	Acre	$11.75	$11.75
Insecticide				
Waterweevil	1.6	Ounce	$2.75	$4.41
Stinkbug Pyrethroid Rice	3.2	Ounce	$2.75	$8.81
Other Chemicals				
Herbicide Surfactant	2.5	Acre	$1.53	$3.82
Fungicide Surfactant	1	Acre	$0.46	$0.46
Fungicides				
Rice Fungicide	1	Acre	30.52	$30.52
Irrigation				
Water Cost	2.75	Acre-Foot	$15.80	$43.45
Irrigation Labor	1.57	Hour	$20.09	$31.54
Machinery Labor				
Tractors/Self-Propelled	1.26	Hour	$20.09	$25.31
Diesel Fuel				
Tractors/Self-Propelled	12.4	Gallon	$4.36	$54.05
Repairs & Maintenance				
Irrigation Equipment	1	Acre	$0.01	$0.01
Tractors/Self-Propelled	1	Acre	$38.66	$38.66
Implements	1	Acre	$26.48	$26.48
Interest on Credit Line			6%	$36.61
Total Variable Costs				$1,016.92
Planned Returns Above Variable Costs:				-$36.92
FIXED COSTS	**Quantity**	**Units**	**$/Unit**	**Total**
Machinery Depreciation				
Irrigation Equipment	1	Acre	$0.24	$0.24
Tractors/Self-Propelled	1	Acre	$37.44	$37.44
Implements	1	Acre	$32.53	$32.53
Equipment Investment				
Irrigation Equipment	$1.84	Dollars	6.00%	$0.11
Tractors/Self-Propelled	$297.34	Dollars	6.00%	$17.84

Implements	$209.81	Dollars	6.00%	$12.59
Management Fee, Owner/Operator Labor	1	Acre	$45.67	$45.67
Rice - Land Charge	1	Acre	$135.64	$135.64
Total Fixed Costs				$282.06
Total Specified Costs				$1,298.98
Returns Above Specified Costs				-$318.98

Table17b. Summary of projected costs and returns per acre; rice west of Houston – second crop; 450-acre farm; surface water, 2023.

REVENUE	**Quantity**	**Units**	**$/Unit**	**Total**
Rice 2nd Crop Loan	16	CWT	$7.00	$112.00
Rice 2nd Crop Premium	16	CWT	$7.00	$112.00
Total Revenue				$224.00
VARIABLE COSTS	**Quantity**	**Units**	**$/Unit**	**Total**
Production Costs				
Fertilizer				
46-0-0`	0.075	Ton	$765.36	$57.40
Custom				
Aerial Application	1	Acre	$8.07	$8.07
Top Dress	1	Acre	$9.31	$9.31
Rice Hauling	19.3	CWT	$0.43	$8.30
Rice Drying	19.3	CWT	$1.31	$25.28
Miscellaneous				
Commission	16	CWT	$0.08	$1.28
Check Off	16	CWT	$0.08	$1.28
Rice Storage	16	CWT	$0.32	$5.12
Insecticide				
Stinkbug Rice	0.22	Pint	$19.89	$4.42
Irrigation				
Water Cost	1.9	Acre-foot	$18.89	$35.89
Irrigation Labor	0.71	Hour	$20.09	$14.26
Machinery Labor				
Tractors/Self-Propelled	0.23	Hour	$20.09	$4.62
Diesel Fuel				
Tractors/Self-Propelled	1.95	Gallon	$4.36	$8.50
Repairs & Maintenance				
Irrigation Equipment	1	Acre	$0.01	$0.01
Tractors/Self-Propelled	1	Acre	$8.77	$8.77
Implements	1	Acre	$1.53	$1.53

Interest on Credit Line			6%	$7.25
Total Variable Costs				$201.30
Planned Returns Above Variable Costs:				$22.70
FIXED COSTS	**Quantity**	**Units**	**$/Unit**	**Total**
Machinery Depreciation				
Irrigation Equipment	1	Acre	$0.24	$0.24
Tractors/Self-Propelled	1	Acre	$7.92	$7.92
Implements	1	Acre	$1.70	$1.70
Equipment Investment				
Irrigation Equipment	$1.84	Dollars	6.00%	$0.11
Tractors/Self-Propelled	$61.52	Dollars	6.00%	$3.69
Implements	$27.67	Dollars	6.00%	$1.66
Management Fee, Owner/Operator Labor	1	Acre	$10.44	$10.44
Total Fixed Costs				$25.76
Total Specified Costs				$227.06
Returns Above Specified Costs				-$3.06

Annual usage rates for tractors are projected at 600 hours, with capital recovery factors calculated over an 8-year useful life. Annual usage rate for the combine was estimated at 200 hours with the capital recovery factor calculated over a 10-year useful life. Fixed costs shown in the budget represent the cost of owning machinery and equipment and are the annualized capital recovery cost for owned durable items. No adjustment was made in aerial application costs for irregular-shaped fields. The interest rate assumed on the projected operating loan for this budget is 6 percent.

The budgeted fertility program for the main crop includes a base fertilizer application, one pre-flood application, and one top-dress application. The total main crop fertilizer application is comprised of 183 units of N, 59 units of P, 39 units of K, and 4.3 units of S. The budgeted main crop herbicide program includes an initial ground applied treatment of clomazone, an aerial application of a general tank-mix over the total planted acreage to control sedges, grasses, and broad-leaf weeds along with a follow-up aerial application over one-half the planted acres to control escaped weeds. The budgeted pesticide program for the main crop includes one fungicide application to control foliar diseases, an insecticide application to control water weevils, and a pyrethroid application to control rice stink bugs.

The budgeted surface water irrigation program for the main crop includes 1.57 hours per acre of labor for three flushes, flood maintenance, and draining. A base water charge of $66.91 is charged to the main crop. Total main crop water usage is budgeted at 2.75 acre-feet. For the purposes of this budget, a relatively inexpensive surface water rate of $15.80 per acre-foot is assumed. Based on discussions with AFPC representative farm panel cooperators, this inexpensive surface water irrigation system would be similar to costs incurred under a groundwater irrigation system. Actual Lower Colorado River Authority (LCRA) agricultural irrigation use rates for 2022 ranged from $39.19 to $69.44 per acre-foot delivered (depending on which irrigation division serves a particular producer and, if in the Garwood Agricultural Division, where the farm is located

in the canal system). These rates are more than twice the per acre-foot rates assumed in this analysis, so producers utilizing these budgets for planning purposes are encouraged to use figures realistic for their respective area and operation, as this will significantly impact projected returns. It should be noted that at the time this budget was developed, the actual price of surface irrigation water for production of the 2023 crop was uncertain.

The budgeted fertility program for the ratoon crop consists of one top-dress application of urea. The total ratoon crop fertilizer application is comprised of 69 units of N. The budgeted pesticide program for the ratoon crop includes one application to control rice stink bugs. The budgeted surface water irrigation program for the ratoon crop includes 0.71 hours per acre of labor for one flush, flood maintenance, and draining. Total ratoon crop water usage is budgeted at 1.9 acre-feet; as mentioned previously, actual 2023 surface water charges are unknown at the time of publication.

No Agriculture Risk Coverage (ARC) or Price Loss Coverage (PLC) payments from USDA-FSA are included in the projected revenue of these budgets. All income estimates assume a projected premium of $7.00/cwt over a $7.00/cwt loan rate. The first crop budgeted scenario generates a slight loss of $36.92/Acre after accounting for variable costs. Once machinery depreciation and investment, owner/operator management draw, and cash rent are applied, the expected loss per acre after accounting for all specified expenses is $318.98/Acre. The second crop is projected to realize an expected return above variable costs of $22.70/Acre; the second crop results in a slight loss of $3.06/Acre after allocating machinery costs and management fees. The second crop is much closer to breakeven, primarily because most of the overhead expenses are allocated to the first crop. Expected return after accounting for all specified costs for the first and second crops combined is a loss of $322.04/Acre.

An enterprise budget is a statement of what is expected if particular production practices are used to produce a specified amount of product and is based on the economic and technological relationships between inputs and outputs. The scenarios shown in Tables 17a-17b represent general guides and are not intended to predict the costs and returns from any particular farm's operation. For more details related to these budgets, please contact your local county Texas A&M AgriLife Extension Service office or go to the Texas A&M AgriLife Extension service budget web site maintained by the Texas A&M University Department of Agricultural Economics at http://agecoext.tamu.edu/resources/crop-livestock-budgets/.

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