外國 研究動向
Foreign Weed Science

Rice Production and Weed Control in Arkansas and Texas in the United States

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美國 南部 Arkansas 및 Texas 地域의 稻作과 雜草防除

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INTRODUCTION

Trial plantings of rice in the United States were made in Virginia in 1609. It is known, however, that the rice growing was firmly established since 1694 when a ship from Madagascar was blown off course by a storm to the colony of Charleston, South Carolina. A handful of rice grains was given to the governor of the colony by the captain as gratitude for their help. The rice was planted in the garden of the governor's residence.

Until about 1890, rice in the U.S. was grown principally in the southeastern states, although some was grown along rivers in the south central states.

Rice production in the prairie of southwest Louisiana rapidly increased since 1888 with successful experimental plantings from 1884 and in the adjacent part of Texas. Some rice was grown along rivers in Arkansas in early years but it did not become an important cash crop until 1904 when rice was produced in Grand Prairie. Experimental plantings were made near Butte Creek in the Sacramento Valley in California in 1909 and rice became a commercial crop about 1912. Rice production has been of considerable importance in the delta area of Mississippi since about 1948. Rice production has grown steadily from this early time and has become one of America's most important farming enterprises.

Rice varieties can be divided generally into three main groups: short, medium, and long grain varieties. All these rice varieties are grown in the United States, primarily short grain in California, medium grain in Louisiana, and long grain in Arkansas and Texas. Rice production in the United States is shown in the Table 1.

I. RICE PRODUCTION IN ARKANSAS

Rice acreage in Arkansas reached 273,000 ha in 1954 from the beginning 186 ha in 1904. Allotments stabilized acreage around 200,000 ha level for 20 years during 1954-1973. Marketing quotas were lifted in 1974 and rice acreage has rapidly increased.

Arkansas is now the leading rice producing state in the United States with over 35 percent of the total rice production.

Rice yield per acre has doubled in the past 25 years primarily by introduction of new technology such as new herbicides, improved varieties, better fertilization methods, and improved cultural management. During the 1970's, average production tended to level out after peaking at 5,650Kg per ha in 1971. Refer to Tables 2 & 3 for rice production

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Table 1. Rice Production in U.S.A.

State	1979		1980	
	Harvested (1,000 ha)	Product'n (1,000 mt)	Harvested (1,000 ha)	Product'n (1,000 mt)
Arkansas	458	2,050	522	2,284
California	211	1,529	229	1,539
Louisiana	214	937	246	965
Mississippi	84	185	95	427
Missouri	14	61	18	82
Texas	226	1,066	238	1,068
U.S. Total	1,207	5,828	1,348	6,365

Table 2. Arkansas: Acreage, Yield, Production, and Value of Principal Field Crops, 1979 and 1980.

Crop	Harvested acreage		Unit	Yield per acre		Production		Season average price		Value of production	
	1979	1980		1979	1980	1979	1980	1979	1980	1979	1980
	Thousand acres			Units		Thousand units		Dollars		Thousand dollars	
Corn for grain	35	37	Bu.	58.0	28.0	2,030	1,036	2.70	3.55	5,481	3,678
Cotton	530	645	Lb/bale[1]	549	330	606	444	.6530	.7710	189,945	164,316
Cottonseed	–	–	Ton	–	–	215	181	133.00	129.00	28,595	23,349
Hay, all	933	921	Ton	1.90	1.33	1,774	1,221	42.50	47.00	75,395	57,387
Lespedeza seed	2.4	1.5	Lb/cwt.	374	310	900	465	37.00	63.00	333	293
Oats	34	33	Bu.	65.0	63.0	2,210	2,079	1.66	1.85	3,669	3,846
Rice	1,020	1,280	Lb/bag[2]	4,320	4,110	44,064	52,615	10.60	[3]	467,078	[3]
Sorghum for grain	176	103	Bu.	62.0	19.0	10,912	5,887	2.21	2.88	24,116	16,955
Soybeans for beans	5,150	4,350	Bu.	28.0	16.0	144,200	69,600	6.44	8.05	928,648	560,280
Sweet potatoes	0.7	0.6	Cwt.	76	60	53	36	9.00	10.00	477	360
Tall fescue seed	14.0	13.0	Lb/cwt.	295	260	4,130	3,380	22.00	18.50	909	625
Wheat, all	420	820	Bu.	35.0	38.0	14,700	31,160	3.71	3.80	54,537	118,408

[1] Yield in pounds of lint per acre; production in equivalent 480-pound net weight bases.

[2] Yield in pounds per acre, production and price in equivalent 100-pound bags.

[3] State estimates not available.

Table 3. Rice Crop: Acreage, Yield, Production, Price, and Value.

Year	Planted	Harvested	Yield per acre	Unit	Production	Season av. price per unit	Value of production
	Thous. acres	Thous. acres			Thous. units	Dollars	Thous. dollars
1971-80 av.	815	810	4,495	Lb-Cwt.	36,411	8.88	323,429
1976	850	847	4,770	Lb-Cwt.	40,362	7.25	292,625
1977	840	837	4,230	Lb-Cwt.	35,396	9.79	346,527
1978	1,100	1,090	4,450	Lb-Cwt.	48,505	8.47	410,827
1979	1,030	1,020	4,320	Lb-Cwt.	44,064	10.60	467,078
1980	1,300	1,280	4,110	Lb-Cwt.	52,615		

and its economic value. There are 51,773 farms on 13.4 million ha with an average farm size of 118 ha (1978).

A. Rice Growing Area

Rice is produced in more than 40 counties in Arkansas, mostly in the eastern half of the state along the Mississippi River. Most of the recent increase in acreage has been in northeast Arkansas. Western Arkansas is topographically not suitable for rice growing with hills and mountains.

More than 90% of Arkansas rice in dry-seeded either by drill or by airplane on a dry seedbed, then covered by light harrowing or disking. In southeastern countries, which represent less than 10% of the total acres, rice is sown into the water by airplane immediately after the field is flooded. The reason for water-seeding in this area is mainly

Table 4. Relative Performance of Commercial Rice Varieties Grown in Arkansas.

Grain Type and variety	Grain yield potential (%)[1]	Days to 25% Heading (No.)[2]	Relative straw strength[3]	Milling yield		Potential value milled Rice (%)[4]	Reaction to diseases[5]					
				Head rice (%)	Total (%)		Sheath blight	Blast	Stem rot	Str't head	Kernel smut	Brown spot
Long-grain												
Starbonnet	100	107	2	64	71	100	6	5	7	3	6	6
		105	3	59	70	103	6	6	7	3	7	4
Lebonnet	103	89	3	63	72	102	8	2	7	3	4	4
Labelle	86	81	3	66	72	87	8	2	6	2	5	5
Medium-grain												
Nato	107	98	6	70	73	106	5	8	6	6	6	5
Nova	112	96	4	66	72	107	5	4	5	7	4	5
Brazos	120	88	5	66	74	116	7	8	5	5	3	6
Mars	110	92	3				6	6	7	3	4	6
Short-grain												
Nortai	116	102	5	70	74	116	4	4	5	2	2	4

[1] Calculated for each variety as a per cent of Starbonnet which is the standard at 100 per cent.

[2] Days from seedling to 25 per cent heading: Usually 30 to 45 days are needed till harvest.

[3] Degree of straw strength: 1 - Strongest to 9 - weakest

[4] Value computed using Starbonnet at 100 percent.

[5] Degree of disease susceptibility: 1 - least susceptible to 9 - most susceptible. Ratings indicate potential damage under conditions favorable for development of specific diseases.

because of heavy clay soil with poor drainage facility.

B. Crop Rotation

It is common to rotate rice with soybeans or other adapted crop. Rice followed by soybeans for 2 years is the most common rotation system in about 50% of the rice growers. Another common rotation system is rice for 2 years followed by soybeans for 1 year or soybeans for 2 years followed by rice for 1 year. With acreage expansion, rice for 2 years followed by soybeans for 2 years is also popular.

Rice can successfully be grown following cotton, but the possibility is great for injury to seedling rice from herbicide residues or to mature rice from arsenic induced straighthead.

Advantages and disadvantages of crop rotation are as follows:

Advantages –

– Seedbed preparation is easier by rice following soybeans.

- Unused phosphate in soybeans is readily available to rice under flooded condition.
- Red rice is much easier to control in upland crops than in rice.
- Possible to control johnsongrass and cocklebur that cannot tolerate a flood.
- Yields are usually higher with less pests.

Disadvantages–

- Rice following milo may be infested with volunteer milo plants that are difficult to control.
- Rice following fish may lodge due to excessive residual nitrogen.
- Levees must be contructed every year.

Crop rotations in order of most common usage are:

1. rice – soybeans
2. rice – soybeans – soybeans
3. rice – rice – soybeans – (soybeans)
4. rice – soybeans – milo – soybeans
5. rice – milo – soybeans
6. rice – lespedeza – oats – soybeans
7. rice – fish – soybeans
8. rice – soybeans – cotton – soybeans

Usually, rice-rice-soybeans system is preferred

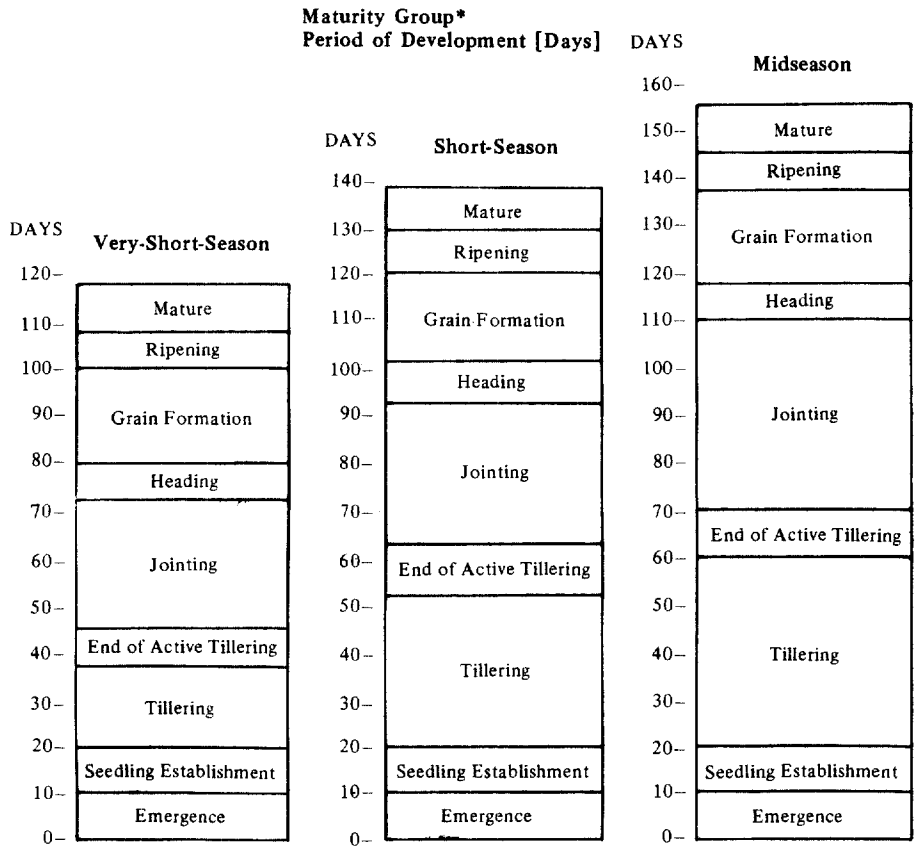

Fig. 1. Stages of Development of Rice Varieties in Arkansas.

under less weed condition and rice-soybeans-soybeans under heavy weed infestation.

C. Rice Varieties

Fourteen or more rice varieties are commercially available in Arkansas and they comprise three maturity groups: very-short-season (100 to 115 days); short-season (116 to 130 days) and mid-season (131 to 155 days). Varieties are further divided into short, medium, and long grain types. Arkansas rice production currently consists of 80% long grain; 18% medium grain, and 2% short grain varieties. A small acreage of waxy type (no amylose in endosperm) has been produced in recent years for use in breweries.

Characteristics of selected varieties are shown in Table 4 and Figure 1.

Groupings of varieties are as follows:

	LONG GRAIN	MEDIUM GRAIN	SHORT GRAIN
Very short season	Labelle Lebonnet Bluebelle Newyer	Vista	
Short season		Della	
Mid-season	Starbonnet Bonnet 73	Mars Nato Saturn Brazos	Nortai

D. Seedbed Preparation and Seeding

Time for seedbed preparation in Arkansas is early April. The first step is plowing or disking 10 or 12.5 cm deep to bury the previous crop residue. The land is then leveled and the final seedbed preparation is done just prior to seeding by a field cultivator or a disk and section harrow.

Land preparation for water-seeded rice differs only in the final seedbed preparation. A rough seedbed is desirable to reduce chances of rice seed or young plants from drifting in the flood. Field cultivators or spring-tooth harrows that will leave shallow furrows and ridges are used to prepare rough seedbeds desirable for water-seeding.

Rice can be broadcast or drill seeded. Drill seeding requires less seed and better uniform germination of rice is provided with uniform planting depth. Drill seeding, however, requires more time for seeding than broadcast. When rice is broadcast by an endgate seeder or airplane on a dry seedbed, rice is covered with light harrowing or disking. Most farmers use disk since it provides more uniform coverage of seeds.

When rice is dry-seeded, the seed should be covered 2.5 to 5 cm deep. Shallow seeding (2.5 cm deep) is preferable on rough seedbed that is likely to crust after rain or early in the season when the temperatures are cool. After rains, excessive water should be drained from the field as soon as the soil becomes soaked because rice seedlings will normally not emerge through both soil and water.

Another common method of seeding is broadcasting by airplane into flooded fields. Water seeding is a practical way to obtain stands and control certain weeds and grasses. The seed is sown into the water by airplane immediately after the field is flooded. Water management is critical to insure good stand establishment. Pre-germinated (presoaked) or dry seed can be sown. Water-seeding is favorable for control of weeds such as red rice and barnyardgrass. It may be desirable to drain water shortly after seeding to prevent floating of seeds or hasten the stand establishment. Water-seeding is common in southeastern Arkansas where soils are heavy clay with poor drainage facilities.

Good stand on levees are important to obtain additional yield. Seeding on levees is done just prior to making the last trip with the levee disk. Seeding rates are affected by seedbed condition, seeding method, quality of seed and seeding date. Under average conditions, 100-130 Kg. of clean viable seed should be drilled per ha. Where rice is broadcast, dry or water seeded, the seeding rate should be higher from 120 to 170 Kg per ha.

It is desirable to have 15-20 plants per square foot to insure satisfactory yield. Plant populations as low as 6-8 plants per square foot may provide

satisfactory yields if tillering (stooling) is good and weeds are controlled. Stand density above 30 plants is excessive and may intensify lodging and disease damage resulting in reduced yield. Higher seeding rate is desirable for late seeding.

Favorable seeding dates may range from April 15 to June 20, depending on the variety, soil temperature, weather conditions, location and method of seeding. Table 5 shows suggested seeding dates for selected varieties in Arkansas.

Table 5. Favorable Seeding Dates of Adapted rice Varieties.

Grain Type and Variety	Seeding Date[1]		
	Beginning	Optimum	Cut-Off
Long-Grain			
Starbonnet	April 10	April 20-May 5	May 20
Bonnet 73	April 10	April 20-May 5	May 20
Labelle	May 10	May 20-30	June 20
Lebonnet	May 1	May 10-20	June 20
Medium-Grain			
Nova 76	April 20	April 25-May 10	June 10
Nato	April 20	April 25-May 10	May 30
Brazos	May 1	May 5-15	June 10
Short-Grain			
Nortai	April 15	April 25-May 5	May 30

[1] Dates are based on available information and are to be used as guides. Adjustments of a few days may be need for locations other than Central Arkansas.

E. Water Management

Once seedling stand is established, herbicide application and water management take place. Rice seedling will reach 1-2 full-leaf stage 7-10 days after seeding which is timing for butachlor+ propanil application. Farmers will try to minimize irrigation or flushing after seeding until permanent flood timing unless it is required for facilitation of germination or activation of butachlor.

Almost all farmers use underground water by pump for their rice. On the average, 120-240 cm of water per ha is required to complete rice season. The amount of irrigation water may range from 110-600 cm per ha. depending on the ability of soil to retain a flood and the water management philosophy of the grower.

Most of the wells are 20-60m deep and it costs $5,000 to as much as $40,000. Water pumping costs range from $2-$4 per 6 cm per ha. Alkaline water containing calcium and magnesium bicarbonates is a problem in Stuttgart area which is the major rice producting area as the well gets deeper and deeper for source of irrigation water.

Rice should be flooded (permanent flood) after the seedlings reach a minimum height of 6 inches which will usually be 3-4 weeks after emergence. A continuous shallow flood (5-10 Cm) for the season is desired to minimize nitrogen loss, weed reinfestation, energy costs, and water use. However, draining may be necessary for one or more of the following reasons:

1. Exposure of aquatic weeds to herbicide: ducksalad, redstem, eclipta spp. etc.,
2. Algae (chara spp.) or scum (algae mat) control,
3. Rice water weevil control,
4. Seedling chlorosis due to high pH and
5. Control of straighthead which is a physiological disorder caused by arsenic.

The rice field will be flooded again after about 2 weeks of drainage and maintain the flooded condition until 2-3 weeks before harvesting when the final drainage will take place.

F. Fertilizer Requirements

Nitrogen is essential to obtain maximum grain yield. 90-145 Kg of nitrogen is required to produce satisfactory yields per ha. Nitrogen is generally applied 2-3 split top dressing. First application will be 45-55 Kg/ha at right before permanent flooding, second with 55 Kg/ha at 7-8 weeks after emergence or before second flooding and third with 20-30 Kg/ha at booting stage. Fertilizer is applied by airplane and flying cost is $2-3 per acre which is cheaper than $4.50 of herbicides since it requires less time and risk.

Phosphorus and potassium are essential for optimum yield but these are not normally applied since rice is rotated with other crops which will be

applied with these fertilizers.

Among other micronutrients, zinc is rather important in some areas. Rice grown on alkaline silt loam soils in central Arkansas has frequently responded to applications of zinc. About 10 Kg of zinc per ha. is recommended on these problem soils at preplant or may be up to 15 days after seedling emergence. Sources of zinc are chelates, organic

Table 6. Weeds of Arkansas in Rice Fields.

Common Name	Scientific Name	Other Name(s)
Algae (blue-green, green)	*Alternathera philoxerodies*	moss, Scum, Alligatorgrass
Ammannia	*Ammannia coccinea*	Purple ammannia, Redstem, Toothcup
	Ammannia teres	Pink ammannia, Redstem, Toothcup
Arrowhead	*Sagittaria montevidensis S. latifolia*	Common arrowhead
	S. cuneate, S. graminea	Grassleaf arrowhead
Barnyardgrass	*Echinochloa crus-galli*	Watergrass, Bluestem Millet, Baronetgrass.
	E. colonum	Junglerice, little barnyardgrass, short-millet.
	E. crus-panonis	Glufcockspur, cattail grass
Beakrush	*Rhynchospora corniculata*	Spearhead, Hornedrush Umbrella weed, Tadpole sedge, Ace of spades
Bulrush	*Scirpus mucronatus*	Rough-seed bulrush,
	S. Fluviatilis	River bulrush
	S. acutus	Hardstem bulrush
Cattail	*Typha sp.*	Flags, Tules, reed-mace
Chara	*Chara sp.*	Stinking moss
Cutgrass	*Leersia oryzoides*	Sawgrass
Dayflower	*Commelina communis*	Wandering Jew
Ducksalad	*Heteranthera limusa*	Water lily
	H. reniformis	Mudplantain
Eclipta	*Eclipta alba*	Tagoweed, Yerba-de-tago
Fimbristylis	*Fimbristylis sp.*	Hoorahgrass
Flatsedge	*Cyperus sp.*	
	C. erythrorhizos	Redroot flatsedge
	C. articulatus	Jointed flatsedge, jointed sedge, onions.
	C. iria	Rice flatsedge, umbrella sedge
	C. strigosus	False nutsedge, Straw-colored sedge
	C. esculentus	Yellow Nutsedge, Yellow nutgrass, Chufa
Goosewood	*Sphenoclea zeylanica*	Hollowstem
Northern jointvetch	*Aeschynomene virginica*	Sensitive jointvetch curly indigo, Bashfulweed, coffee weed.
Knotgrass	*Paspalum distichum*	Water bermudagrass, Jointgrass, lake-grass
Morningglory	*Ipomoea sp.*	
	I. lacunosa	Purple leaf or small flower morningglory
Morningglory	*I. hideracea*	Ivyleaf morning-glory
	I. purpurea	Tall morningglory
	I. wrightii	Palmleaf morningglory
Black nightshade	*Solanum nigrum*	Groundcherry
Fall panicum	*Panicum dichotomiflorum*	
False pimpernel	*Lindernia sp.*	
Pondweed	*Potamogeton sp.*	
Red rice	*Oryza sativa*	Vermillion red rice, Italian red rice
Hemp sesbania	*Sesbania exaltata*	Coffeebean, coffee-weed, tall indigo, seenabean
Broadleaf signal-grass	*Bracharia platygphylla*	Signalgrass, Bracharia
Smartweed	*Polygonum sp.*	Knotweed, pepper-weed
Spikerush	*Eleocharis sp.*	
	E. obtusa	Blunt spikerush
	E. purvula	Dwarf spikerush
	E. guadrangulata	Squarestem spikerush Foursquare
Sprangletop	*Leptochloa sp.*	
	L. panicoides	Tight-head sprangle-top, Ray-grass, Chrismastreegrass, Feathergrass
	L. tascicularis	Loose-head sprangle-top
Waterhyssop	*Bacopa rotundifolia*	
Waterprimrose	*Jussiacea sp.*	Primrose, willow.

complexes, inorganics, mixtures, frits, and inorganic zinc ammonia complexes. Approximately 15% of the Arkansas rice is grown in fields which are affected to some extent by alkaline or saline soil conditions. Rice seedling affected by zinc deficiency will initially lose turgidity and pale green color appears on the basal half of the leaf and leaves become chlorotic and start to die after 3-7 days.

G. Weed Control

Weeds compete with rice for light, nutrients, space, water and other growth requirements. Weeds reduce grain yields, lower the market value, increase the cost of production, harvesting, drying and cleaning. In 1975-77, the estimated direct losses from weeds and the cost of their control represented about 28% of the value of the crop annually or about $300 million per year.

1. Weed Species

About 80 species of weeds in about 40 genera cause economic losses in rice in the United States and are classed as aquatic-semiaquatic plants. Some germinate only in flooded soil, some germinate in an upland environment but grow in flooded soil, and some can germinate and grow in either environment.

Weeds commonly found in rice fields in Arkansas are illustrated and described in Table 6.

It is estimated that the losses due to weeds in Arkansas exceed $60 million in 1977. Competition study have shown that one barnyardgrass per square foot reduced rice yields as much as 25%.

Some common troublesome weeds in Arkansas are as follows:

a) Grasses
- Barnyardgrass: virtually all rice field is infested
- Sprangletop: 15% of total paddy is infested and increasing in Arkansas, Woodruff and Craighead counties.
- Broadlead signalgrass: 10% of total paddy is infected.

b) Aquatics
- Ducksalad
- Redstem
- Eclypta
- Gooseweed

About 10% total rice is infested and the weeds are well spread over the rice area.

c) Broadleaves
- Cocklebur
- Morningglory
- Northern Jointevetch
- Hemp sesbania

2. Weed Control

The best approach to controlling weeds in rice is to use an integrated system that combines preventive, cultural, mechanical, chemical and biological practices. Cultural and mechanical practices are important components of weed control programs for rice, but herbicides are essential for a control system to be effective. Most U.S. rice is treated with herbicides each year; about 80% of it receives multiple herbicide treatments.

Continued reliance on such herbicides as propanil, molinate, 2, 4, 5-T, 2,4-D and MCPA has caused an increase of tolerant weed species such as knotgrass, morningglory, panicum, pondweed, smartweed, sprangletop, spreading dayflower, umbrellasedges, and water primrose.

Most common herbicide application systems are as follows:

a) Propanil followed by (fb) propanil

90% of total rice is treated with propanil at least one time. About 60-70% of growers adopt this system to control grasses and some broadleaf weeds. First application is made with 934 ml/10a at 2 weeks after seeding. Second treatment will follow after another 2 weeks with 700 ml/10a.

b) Propanil fb molinate granule

Propanil is treated at 2-3 weeks after seeding with 934 ml/10a and rice field will be flooded 1 week after treatment. Ordram granule is applied at 4-6 weeks after seeding with the rate of 3.36Kg/10a to control barnyard-grass escaped under flooded

condition. Twenty to thirty percent of total area is treated with this sytem.

c) Propanil + residual herbicides

Residual herbicides for this tank-mix are butachlor, thiobencarb, pendimenthalin and oxadiazon. Very little bifenox is being used because of severe corp injury and poor efficacy on barnyard grass. Usually application timing for this mixture is 2-3 weeks after seeding at suitable growth stage of rice seedling as well as weeds.

d) 2,4,5-T or 2,4-D

If the farmer still has aquatic weed problems, it is recommended to use 234 ml-350 ml/10a of 4 lb/gal 2,4-D amine or 350 ml/10a of 4 lb/gal 2,4,5-T amine or silver ester. 2,4,5-T is commonly used and special attention is required to avoid drift damage to neighboring crops.

*Remarks: Upjohn has been testing biocontrol agent, "Collegol" to control northern jointvetch. It is expected that the product will be registered in 1982 in tank-mix with acifluorfen to control Hemp sesbania as well as northern jointvetch.

H. Diseases and Insects

The major diseases in Arkansas are caused by fungi. These include blast (*Pyricularia oryzae*), stem rot (*Sclerotium oryzae*), and sheath blight (*Rehizoctonia solans*). Blast disease is not serious problem in general, since most of the rice varieties are resistant to blast. The latest epidemic of blast was in 1979 when the weather was wet/humid with high temperatures during the rice growing season. Stem rot and sheath blight are soilborne and are the most important diseases since most varieties are susceptable to these diseases. Benlate is being used and some new chemicals such as Du-Ter, super Tin, etc. Other diseases present is Arkansas are brown spot, kernel smut and straighthead. Straighthead is a physiological disorder caused by arsenic in the soil and this is controlled by cultural practices with resistant varieties.

The insect that causes the most damage to rice each year is the rice water weevil. The major damage is pruning of rice roots by larvae with subsequent reduction in crop stand, vogor, and yield. Carbofuran insecticide is being used to control this insect.

Occasionally rice stinkbug may cause economic damage but this insect is not usually a threat. Besides, fall armyworms and chinch bugs sometimes attack rice; however, damage is usually insignificant.

II. RICE PRODUCTION IN TEXAS

The first attempt to grow rice in Texas was made in 1850. In 1892, 70 ha of rice were grown all on the Beaumont prairie. In 1980, Texas marked the third largest rice producing state in the United States, next to Arkansas and California with 239,-000 ha.

There are 186,000 farms on 56 million ha of farm land and average farm size in about 302 ha per farm which is almost twice larger than the average of the U.S.

In Texas, rice is the fifty largest field crop, following cotton, sorghum, soybeans and corn. Yield of rice per ha in 1980 was 4,737 Kg which is sightly less than 4,931 Kg of the U.S. average. The highest yield per ha was recorded in 1967 with 5,604 Kg.

The Texas rice farming may be characterized as follows:

1) Many of the rice growers are lease farming, although the farming size is much larger than the other states. The grower owns equipment and is responsible for farm operations and profit is usually shared with the land-owner on 50-50 basis. 2) Second crop (ratoon crop, stubble crop) is common with very early maturing varieties. 3) Soil type varies greatly within the rice growing area from fine sandy soil to heavy clay soil even within one piece of field. 4) Water supply is limited with 889-1,400 mm of annual rainfall.

A. Rice Growing Area

Rice in Texas is grown in 20 counties along the Gulf Coast where relatively more rain falls than

in other areas. Rice acreage has increased steadily for the last five years, although the growth rate was small.

It is estimated that about 85% of 239,000 ha was dry-seeded and the remaining 15% was water-seeded in 1981. Most counties west of Houston are usually dry-seeded and east of Houston tends to have more water-seeded areas, although dry-seeding may increase if the weather during the planting season is dry.

Planted Acreage of Rice (1979 - 1981).

Year	1,000 ha
1976	206
1977	203
1978	227
1979	227
1980	239
1981	239

B. Crop Rotation

The Texas Gulf Coast Prairie has traditionally been cattle country with rangeland occupying most of the acreage. When rice culture began, weeds were not a problem for several years. As weeds became prevalent, the rice growers moved to weed-free virgin sod and grew a new rice crop and the old ricelands reverted to grazing.

Until the late 1960's, land was normally in rice for one to two years followed by pasture for two to five years. The recent development of improved rice management practices allows land to remain out of rice production only one or two years. This does not provide time to establish and utilize permanent pasture. Consequently, the recent trend has been toward separate permanent pastures and ricelands in a short rotation system with the other row crops.

Soybeans have exhibited potential as a profitable alternate crop to rice in the early 1970's. Major crop rotation systems at present are alternate cropping of rice and soybeans east of Houston where red rice is a serious problem and rice for 2-3 years followed by soybeans in other areas.

Advantages of rotation with soybeans would be:

1) Rice field equipment is easily adaptable to soybeans.
2) The timing sequence in land preparation, planting and harvesting of soybeans is compatable with rice.
3) Both crops require level land that can be easily drained.
4) Utilization of fertilizers are ideal.

C. Rice Varieties

For the past 20 years, long grain varieties have pre-dominated in Texas. Now, more than 95% of the rice is long-grain with very small acreage of medium-grain.

The rice varieties available in Texas are very similar to Arkansas. Labelle is the leading rice variety in Texas as shown on Table 7 with its' first and second crop yield potential and its' high milling yield.

Table 7 Rice Varieties Grown in Texas (1978).

Variety	% of acreage
Labelle	87.9
Lebonnet	6.8
Bluebelle	1.6
Starbonnet	0.4
Nato	2.4
Brazos	0.7
Saturn	0.2

In addition to the above varieties, Newrex, which is an early maturing long-grain variety, was released in 1979.

In 1981, a new rice variety, Bellemont, was released. This is an early maturing, long-grain variety with superior lodging resistance. Bellemont variety is the first semi-dwarf ever developed in the United States. The average height of Bellemont is 81 cm, compared to 117 Cm for Labelle, which is the popular variety. If this variety becomes the leading rice variety in the U.S., there may be a new opportunity for glyphoste to control red rice with selective

equipment. It is desired by many farmers in Texas to grow rice continuously if possible. It is also proven by the Beaumont Experiment Station that rice can be successfully grown in many successive years with good management.

D. Seedbed Preparation and Seeding

Seedbed preparation and seeding method will not be discussed for Texas since they are identical to Arkansas.

Seeding method depends on soil type, weather conditions and producer preference. The main factors to consider are uniformity of seedling establishment and the weed problem. There is, in Texas, no evidence of a yield advantage of drilled over broadcast seeding or dry over water-seeding if stands are adequate. It is noted that there is some confusion with terminology for planting method in some growers in Texas. Typical example is that dry-seeding is referred to sow pregerminated (pre-wet, pre-soaked) seeds into water by some rice growers.

The optimum seeding dates in Texas are earlier than Arkansas. Recommended seeding dates are March 25-April 15 for western area and April 1-April 15 for the eastern area.

E. Water Management

Field should be level enough to maintain 7.5 - 15 cm of water depth for weed control. During the seedling growth period, soil moisture should be adequate but should not be flooded. Excessive flooding can reduce seedling survival and tillering. When possible, delay first flood until tillering has begun or about 3 weeks after seedling emergence. Another significance of delaying flood is to save cost for water. Amost all rice is irrigated by underground water, which is 80-180m deep.

Other water management is basically the same as Arkansas regardless of the second crop. It is recommended to drain water early enough before harvest so that soil can be dry to minimize mechanical damages to stubble.

Soil moisture will be kept but not flooded for about two weeks after harvest until new tillers grow up to 10-15 Cm high.

F. Fertilizer Requirements

Most Texas soils respond to 45 Kg of phosphorus per ha. Light soils usually respond to 70 Kg of nitrogen, while heavy soils require about 90 Kg per ha. Potassium is not generally required except for Katy fine sandy loam soil. Recommended fertilizer requirements by soil types are as follows:

	$N - P_2O_5 - K_2O$ (Kg/10a)
Beaumont Clay	9.0 - 4.5 - 0
Lake Charles Clay	9.0 - 4.5 - 0
Bernard Clay Loam	9.0 - 4.5 - 0
Katy Fine Sandy Loam	6.7 - 4.5 - 2.3
Hockley Fine Sandy Loam	6.7 - 4.5 - 0
Edna Fine Sandy Loam	6.7 - 4.5 - 0

It is recommended to increase N level by 25% for Bluebelle variety.

Rate is more important than timing of nitrogen. However, as nitrogen rates are increased, timing of application becomes more important. Whenever rice shows nitrogen deficiency, it is desirable to apply nitrogen as soon as possible, regardless of rice growth stage.

It is suggested to apply 10 Kg of zinc sulfate plus 100 Kg of iron sulfate per ha at seeding where soils are alkaline, high in calcium bicarbonate and have normal sodium level.

G. Weed Control

Some of the weeds most commonly found in Texas are barnyardgrass, junglerice, broadleaf signalgrass, red rice, sprangletop, ducksalad, gooseweed, redstem, dayflower, hemp sesbania, northern jointvetch and mexicanweed. Of these, the most abundant and difficult to control weeds are barnyard grass, sprangletop, red rice and dayflower.

It was pointed out by Dr. E. Ford Eastin at Beaumont that sprangletop is now the most serious problem which was shifted from barnyardgrass due to continuous use of propanil in Texas.

The best approach to controlling weeds in rice

involves combination of good cultural, mechanical and chemical practices. In general, red rice is more of a problem in eastern counties and barnyardgrass in western counties.

Proper crop rotation, careful seedbed preparation, land leveling and accurate levee construction, and good water management are suggested in combination with herbicide application.

Chemical weed control appears to be slightly less developed than Arkansas. Herbicide application systems are very similar to other states. Major treatments are:

1) Propanil single or followed by propanil.

The recommended rate of propanil is 900ml per 10a for each treatment not exceeding 1,800ml per 10a per application or 2,500ml per 10a during a season. This the most common herbicide program at present. The initial application is made at the time of 1-3 leaf stage of grasses or less than 5 Cm of broadleaves. Second treatment is applied as needed depending on the second stand of weeds at approximately 7-10 days after the weeds emerged. Permanent flood is then established within 2-4 days after the last treatment to prevent reinfesting weeds.

Rice may be severely injured if carbaryl (Sevin), parathion or malathion are applied within 2-3 weeks of propanil application. After applying carbofuran (Furadan) or Bux, rice should not be treated with propanil.

2) Molinate

Molinate use was developed between 1965-1969 in Texas. Molinate has following use options.

- Preplant incorporation with 350ml/10a only for water-seeded.
- Propanil 900ml + molinate 300ml at early post.
- Molinate single at or after permanent flooding.

3) Propanil + residual herbicides.

Butachlor, thiobencarb and oxadiazon have been tested in Beaumont experiment station since early 1970's. butachlor and thiobencarb have been major pre-emerge herbicides for this tank mixture.

4) Phenoxy herbicides.

This is to control certain broadleaves such as hemp sesbania, northern jointvetch, morningglory, gooseweed and dayflower. The treatment is very limited since cotton, soybeans or sorghum is grown in adjacent field in most cases. The use of phenoxy herbicides is also controlled by the Texas Dept. of Agriculture under the Texas Herbicide Law.

H. Diseases and Insects

Rice diseases occurring in Texas are:

Seedling diseases:

- Seedling blight caused by *Rhizactonia, Pythium, Fusarium*, etc.

Foliage diseases:

- Rice blast *(Pyricularia oryzae)*
- Brown leaf spot *(Helminthosporium oryzae)*
- Narrow brown leaf spot *(Cercospora oryzae)*
- Leaf smut *(Enghloma oryzae)*
- White tip *(naematode, Aphelenchoides besseyi)*

Sheath and stem disease:

- Brown bordered leaf and sheath spot *(Rhizoctonia oryzae)*
- Sheath blight *(Rhizoctonia solani)*
- Sheath rot *(Acrocylindrium oryzae)*
- Stem rot *(Sclerotium oryzae)*

Kernel diseases:

- Kernel smut *(Neuvossia horrida)*
- Kernel spot *(Helmithosporium, Alternaria, Curvularia)*

Physiological disorders:

- Straight head *(arsenic residues)*
- Cold weather injury
- Alkalinity or salinity

Among these diseases sheath blight and stem rot are the most important diseases. These diseases usually infect the rice together and kill the stubbles which may affect the second crop.

Insect pests are basically the same as Arkansas with rice water weevil, rice stinkbug, and fall armyworm except grasshoppers and stalk borers, which are very minor problem. Population of stalk borers is kept very low because of the activity of egg parasites.

I. Second Crop Rice Production

Second crop rice (ratoon culture, stubble crop-

ping) is widely being grown and this may be a unique practice in Texas although Louisiana has some second cropping in the south.

Texas growers are planting over 90% of their acreage to very early and early maturing varieties adapted to second crop production. Average yield for second crop is 8-10 bushels per acre compared to 25-30 bushels for the first crop.

Selection of early maturing variety and seeding date are very important for second crop. The first crop should be before August 10 and no later than August 15. The second crop will be harvested in late October.

Additional phosphorus or potassium is not required but about 67 Kg of nitrogen per ha should be applied immediately after the first crop is harvested.

Research indicates the normal combine cutting height of 42-45 cm stuble is satisfactory for all varieties. Clipping stubble to 25 cm or shorter may delay second crop maturity for 1-3 weeks.

Water management is extremely important for the second crop. During first harvest, the field should be dry enough to support heavy machinery. Flushing or light flooding is recommended right after nitrogen is applied to stubble. Soil should be kept moist but not flooded for about 2 weeks after first harvest until new tillers grow up to 10-15 cm high.

Sheath blight and stem rot diseases should be controlled very well in later growing stage of the first crop. This will facilitate growth of new tillers for second crop.

There is a tendency that panicle size of second crop is much smaller than that of first crop. The latest varieties are not photo-sensitive but the small panicle may be resulted from too early panicle initiation without enough vegetative growth. If a chemical can delay the panicle initiation for 7-10 days, it may be expected to have larger panicle which will hopefully increase the yield of second crop.