Texas Rice

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Aerobic Rice: Production Inputs and Breeding Selection Criteria

In the United States, Australia, and Europe, rice is grown as an irrigated lowland rice culture, while in other regions of the world, irrigated lowland, rainfed, irrigated upland or aerobic, and deepwater rice are grown. Worldwide, 56.9% of the rice acreage is grown to lowland rice, 30.9% is rainfed, 9.4% is aerobic or non-flood, and 2.8% is deepwater (IRRI, 2004-2006). Among these rice cultures, only aerobic rice is grown in nonflooded and nonsaturated soil (the soil is not submerged under water) with supplemental irrigation. Aerobic rice is grown in Latin America, Asia, and Africa. About 35 million acres were planted to aerobic rice in 2006, of which 22.4 million acres were grown in Asia and 6.3 million acres were grown in both Latin America and Africa (IRRI, 2004-2006). Compared to lowland rice farms, most aerobic rice is grown on small, subsistence farms with few purchased inputs. Labor is substituted for capital and most of the production is for family consumption. Market forces (i.e. costs and prices of input and output) have less influence on aerobic rice production systems in Asia and Africa compared to lowland rice farms. However, in Latin America, aerobic rice is grown on large mechanized farms, with market forces having greater influence on technology (Gupta and O'Toole, 1986).

Low Input Aerobic Rice Production System

Aerobic rice is generally known as a low input production system. For example, in a study at Palawan, Philippines, Shively (2001) observed lower fertilizer, pesticide and irrigation labor use in aerobic rice compared to lowland farms. In areas of the Philippines where irrigation costs are high, aerobic rice varieties could replace lowland varieties as a cost-saving measure. The lower yield in aerobic rice can be compensated by its lower irrigation costs (Bayot and Templeton, 2009).

One of the most comprehensive experiments that compared aerobic and flooded rice production was conducted in the Philippines by Bouman et al. (2005). The authors evaluated three aerobic and four lowland rice varieties grown in both flooded and aerobic conditions. The major disadvantage of aerobic rice compared to irrigated rice is its lower grain yield. Average grain yield across varieties was 32% lower in the aerobic conditions than in the flooded conditions in the dry season (December to June) and 22% lower in the wet season (June to November). Total water input, including rainfall and irrigation, when averaged across 3 years during the dry and wet seasons for the aerobic rice culture was 33 and 46 inches, respectively, while it was 55 and 67 inches, respectively, for the flooded rice culture (Bouman et al., 2005). This indicates that aerobic rice culture uses 40 and 32% less total water than the flooded rice culture during the dry and wet seasons, respectively. In terms of the amount of irrigation water applied, aerobic rice culture uses 28 and 11 inches of water for the dry and wet seasons, respectively, while the flooded lowland rice culture uses 49 and 30 inches, respectively. This implies that the aerobic rice culture uses 44 and 62% less irrigation water than the flooded lowland rice culture during the dry and wet seasons, respectively.

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From the Editor ...

Aerobic Rice and Biofortification

Welcome to the August issue of Texas Rice. Our cover story describes a form of rice production referred to as aerobic or irrigated upland rice. Unlike rice production in most of the world, aerobic rice production result in the fields not being flooded most of the season. As a result, aerobic rice production uses far less water than does conventionally flooded rice. While aerobic rice cannot be economically grown in the U.S., due to its lower yields, research conducted at the Beaumont Center on drip irrigation suggests rice yields can be achieved that are equal to that produced with flood irrigation using only 50% of the water. However, the upfront costs of drip irrigation are too high to be offset by decreased water costs. Maybe a happy mid-point can be achieved using increased laser leveling and automated flood-gate controls to provide metered water on an as needed basis. Taking a look through a crystal ball, it is possible that varieties of rice will someday be developed that can be grown like wheat, basically on stored soil moisture and rainfall. These types of rice will undoubtedly have to be produced using transgenic methods. More on that in a moment!

The second article in this issue focuses on the production of rice that is biofortified with iron. Biofortified refers to the rice plants incorporating a sufficient amount of iron in the grain to meet human consumption needs, as contrasted with adding iron as a supplement to the milled rice. Iron deficiency is a huge problem in many countries and is the most widespread nutritional disorder in the world, with over 30% of the world's population suffering from anemia mainly due to iron deficiency. Research by Yang et al. (1998) shows tremendous variation in the levels of iron taken up and incorporated into rice kernels, with the highest levels 2.3 x the mean level. Research by Goto et al. (1999) shows that the concentration of iron in rice grain was increased 2.6 x over normal rice by inserting a soybean ferritin SoyferH-1 gene. While 2.6 x for the transgenic rice appears to be only trivially higher than what is found with conventional high-iron rice, comparing these numbers is a bit misleading. The approached used by Goto et al. was to increase iron concentration in the endosperm instead of in the rice seed's aleurone layer. In other words, most of the iron in conventional rice is removed during milling, while it is located deeper in the kernel in the transgenic rice and not removed during milling.

Earlier, I discussed some of the economic constraints associated with aerobic rice, i.e., the fact that aerobic rice yields less than conventional flooded rice. In the case of transgenic rice, such as the transgenically biofortified iron rice, the challenge is also economical but very different in nature. Unlike aerobic rice, there is no data to suggest that biofortified transgenic rice yields less than conventional rice. The problem is the current non-acceptance of transgenic rice. Many of us are familiar with the problems that arose due to the contamination of U.S. rice with Bayer's Liberty-linked genes. Although no evidence has been presented showing that Liberty-Linked rice is harmful to humans, transgenic rice is currently not accepted for commercial production, thereby barring the gates for international trade. Although transgenic corn, cotton, rapeseed, soybeans, and an increasing long list of transgenic crops are commercially produced around the world, the philosophical debate continues to keep the doors closed for transgenic rice. My guess is that when major rice producing countries that primarily consume the rice that they produce,

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Farming Rice

A monthly guide for Texas growers

Providing useful and timely information to Texas rice growers, so they may increase productivity and profitability on their farms.

Iron-Biofortified Rice

Iron and Its Deficiency in Humans

Iron serves in metabolic or enzymatic processes and in iron storage and transport in humans. Iron in hemoglobin accounts for about 65% of total body iron, averaging about 3.5 g in the adult male and is used to transport oxygen via the bloodstream from the lungs to the rest of the body (Dallman 1986). Iron in myoglobin accounts for about 10% of the total body iron and is used to transport and store oxygen for use during muscle contraction. Iron is used by cytochromes for electron transport in the mitochondria and other cellular membranes, and by non-heme iron compounds and other iron-dependent enzymes that do not contain iron but that require iron as a co-factor or activator. Iron is also used in storage compounds, such as ferritin and hemosiderin, which are primarily located in the liver, reticuloendothelial cells, and erythroid precursors of the bone marrow, and account for 5 to 30% of total body iron, and transferrin, which accounts for about 0.1 % of the total body iron (Dallman 1986).

The recommended daily dietary intake for iron is 12 mg/day for males 10 to 18 years old, 10 mg/day for males older than 18 years, 15 mg/day for females 11 to 50 years old, and 10 mg/day for females older than 50 years (Gebhardt and Thomas 2002). Unfortunately, iron deficiency is the most common and widespread nutritional disorder in the world, with over 30% of the world's population suffering from anemia mainly due to iron deficiency (World Health Organization 2009). Iron deficiency limits the amount of oxygen delivered to cells, resulting in fatigue, poor work performance, and decreased immunity. The World Health Organization estimates that of the 1.62 billion people reported to be afflicted with anemia, of which 293 million are preschool-age children, 305 million are school-age children, 56 million are pregnant women, 468 million are non-pregnant women, 260 million are men, and 164 million are elderly (De Benoist et al. 2008). For the preschool-age children, pregnant, and non-pregnant women, the highest proportion of anemia-affected individuals are in African countries (47.5 to 67.6%), while the greatest number of anemia-affected individuals are in Southeast Asian countries (315 million) (De Benoist et al. 2008). In the U.S., 8% of 1- and 2-year old toddlers are iron-deficient (Brotanek et al. 2007).

Diet and Biofortification

There are two forms of iron in the human diet: heme and nonheme. Heme iron is found in animal-source foods that contain hemoglobin, such as red meats, fish, and poultry. Nonheme iron is found in plant-source foods, such as vegetables and cereals, and is the form of iron added to iron-enriched and iron-fortified foods (ODS 2006).

In regions where iron deficiency is the major cause of anemia, additional iron intake is usually provided through iron supplements to vulnerable groups (e.g. pregnant women and young children). In addition, sustainable strategies for preventing iron-deficiency anemia in the population have included food-based approaches to increase iron intake, such as thru food fortification and diet diversification (De Benoist et al. 2008). Food fortification, which involves adding minerals or vitamins during the postharvest processing of plant products, is a familiar strategy to improve the nutritional value of food products. Recently, a modified form of food fortification, called biofortification, has emerged as a new strategy recommended for solving micronutrient deficiencies. Bioforitifcation, which involves the breeding for staple foods that are high in minerals and vitamins,

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may have the following advantages over fortification in the effort against malnutrition (Bouis 2002):

- Cost-effective - There is no need to buy and add the fortificants to the crop products at the postharvest handling process because the crop already produces the micronutrient in high concentrations;
- Sustainable - Profits from the production of biofortified crops would encourage farmers to continue to produce these biofortified crops; and
- Wider effective reach - Biofortification can reach relatively remote rural areas where fortified food staples currently do not.

Furthermore, while the traditional methods of public health interventions (food supplementation and fortification) require continuous funding for implementation, biofortification requires only the costs for reliable seed production and seed deployment after the biofortified crop varieties are developed and adopted (Mayer et al. 2008). It has been estimated that the largest cost component for a biofortification strategy would be the research costs to breed for biofortified crop varieties, which was estimated to be about $400,000 per year per crop over a 10-year period (Nestel et al. 2005).

Iron-Biofortified Rice

Based on the list of emerging countries (International Monetary Fund 2009) and world rice production statistics (IRRI 2008), 96.9% of the 385 million acres of rice worldwide were grown in developing countries in 2008. It is also in developing countries where most of the rice is consumed as a staple food. Furthermore, rice is consumed as different products covering a wide range of iron contents. Table 1 shows the common serving quantity and iron content of several rice products and a few popular non-rice products. It is therefore logical that research on iron-biofortified rice is being conducted to use rice as a means to increase the iron intake of rice-consuming iron-deficient populations.

Rice grain iron concentration ranged from 4 to 29.5 mg/kg with a mean of 13.1 mg/kg in a study of 286 rice lines by Yang et al. (1998) and ranged from 7.5 to 24.4 mg/kg with a mean value of 12.1 mg/kg in a study of 939 rice lines by Graham et al. (1999). The wide range of iron concentrations suggests that there is potential to increase iron concentration in rice grain. Since iron is not produced by the rice plant, the biofortification approach of increasing iron concentration in the plant involves facilitating iron intake into the plant, improving its transport into the grain, and improving iron storage in the grain (Sautter et al. 2006).

In a study by Goto et al. 1999, the entire coding sequence of the soybean ferritin gene was transferred into *Oryza sativa* (L. cv. Kita-ake) using the *Agrobacterium*-mediated transformation method. The rice seed storage protein glutelin promoter, *GluB-1*, was used to drive the expression of the soybean gene in rice resulting in iron concentrations that were higher in the endosperm of the transformed rice (35.9 to 38.1 µg/g iron) than in untransformed rice (14.3 µg/g iron). Their approach was to increase iron concentration in the endosperm instead of in the rice seed's aleurone layer, which is usually removed through milling in many countries.

In a study by Qu et al. 2005, two kinds of ferritin hyper-expressing rice lines were generated, the DF lines (double transformation line with the introduced soybean ferritin *SoyferH-1* gene under the control of the rice seed storage glutelin gene promoter, *GluB-1*, and the rice seed storage globulin gene promoter, *Glb-1*, [that is, *GluB-1/SoyferH-1* and *Glb-1/SoyferH-1*]) and the OF lines (single transformation line with the introduced *SoyferH-1* gene under the control of *Glb-1* promoter alone [that is, *Glb-1/SoyferH-1*]). The results showed that the maximum iron concentrations in the grain of OF and DF lines was about three-fold higher than that in the non-transformed lines.

Recently, Wirth et al. (2009) have demonstrated that the combined and targeted expression of transgenes for nicotianamine synthase and ferritin resulted in a more than six-fold increase in iron concentration in transgenic milled rice endosperm, the highest increase in iron concentration in a genetically modified rice variety to date.

Iron-biofortified rice has been tested in human food trials. It was shown in food trials conducted in the Philippines that women who consumed iron-

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biofortified rice without making any other changes in their diet increased their total daily iron intake (Haas et al. 2005). Subjects that consumed high-iron rice ‘IR68144–2B-2–2-3’ (3.21 mg/kg iron) had a total iron intake of 10.16 mg/day, with 1.79 mg/day iron coming from rice. In comparison, subjects that consumed a local low-iron rice variety ‘C4’ (0.57 mg/kg iron) had a total iron intake of 8.44 mg/day, with 0.37 mg/day iron coming from rice. This study showed that consumption of biofortified rice, without any other changes in diet, is effective in improving iron stores of women with iron-poor diets in the developing world.

Continued research on increasing iron concentration in the rice grain endosperm, developing high iron rice lines into region-adapted varieties, as well as conducting successful human food trials are necessary for the application of iron-biofortified rice in populations affected by iron deficiency. For more information, please consult the following references:

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Table 1. Iron content per common serving quantity of selected foods (Gebhardt and Thomas 2002).

Description	Common Serving Quantity	Weight (g)	Iron Content per Serving Quantity (mg)
Rice Chex	1 ¼ cup	31	9.0
Rice Krispies	1 ¼ cup	33	2.0
Rice Krispies Treats Cereal	¾ cup	30	1.8
Puffed rice	1 cup	14	4.4
Puddings, rice, ready-to-eat	4 oz	113	0.3
Rice, brown, long-grain, cooked	1 cup	195	0.8
Rice, white, long-grain, enriched, parboiled, cooked	1 cup	175	2.0
Rice, white, long-grain, enriched, parboiled, raw	1 cup	185 g	6.6
Rice, white, long-grain, enriched, instant, prepared	1 cup	165	1.0
Rice, white, long-grain, enriched, regular, cooked	1 cup	158	1.9
Rice, white, long-grain, enriched, regular, raw	1 cup	185	8.0
Snacks, Rice Krispies Treats Squares	1 bar	22	0.5
Snacks, rice cakes, brown rice, plain	1 cake	9	0.1
Soup, chicken with rice, canned, prepared with equal volume water	1 cup	241	0.7
Wild rice, cooked	1 cup	164	1.0
Fast foods, hamburger; double, regular patty; with condiments	1 sandwich	215	5.5
Fast foods, chicken fillet sandwich, plain	1 sandwich	182	4.7
Fast foods, french fries	1 large	169	1.3
Egg, whole, cooked, poached	1 large	50	0.7

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Table 1. Correlation between traits in an aerobic rice, estimated from data presented by James Martin et al. (2007).

Traits	Leaf Area Index at Flowering	Root Length at Flowering	Root Volume at Flowering	Root dry Mass at Flowering	Plant Mass at Flowering	Panicle Density	No. of Filled Grain per Panicle	Grain Yield
	LAI	RtLng	RtVol	RtMass	PltMass	PclDen	FldGrn	GrnYld
RtLng	0.01							
RtVol	0.49	0.27						
RtMass	0.52	0.49	0.34					
PltMass	0.56	0.28	0.21	0.79				
PclDen	0.51	0.37	0.42	0.68	0.71			
FldGrn	0.13	0.49	0.14	0.83	0.81	0.56		
GrnYld	0.44	0.31	0.16	0.89	0.88	0.80	0.85	
Water Use Efficiency	0.39	0.34	0.15	0.87	0.79	0.83	0.80	0.98

Aerobic rice has the advantage in that it demands less labor compared to lowland rice. Bayot and Templeton (2009) estimated that labor cost for aerobic rice in China was $11/acre less than that of lowland rice, while Bouman et al. (2002) estimated that labor cost of aerobic rice was 55 to 73% less compared to lowland rice.

Bouman et al. (2002) observed differences in input costs in two aerobic rice- growing areas in China. In the Hanjiachuan area, paid-out costs (the costs of all inputs, except own labor) in aerobic rice were 16% lower than that in lowland rice. Aerobic rice farms in Hanjiachuan were managed by the farmer cooperative, while the lowland rice farms were managed by private farmers. In the Guanzhuang area, paid-out costs in aerobic rice were 17% higher than that of lowland rice. The differences of input costs were due to differences in cultural practices between the two rice cultures. Higher pesticide costs in aerobic rice were due to the use of pre-emergence herbicides that were not used in lowland rice. Also, the higher costs for labor in aerobic rice were due to contract labor for land preparation, sowing and harvest, whereas in lowland fields these were done by their own labor.

One of the advantages of planting aerobic rice is that it can be rotated with other popular aerobic crops, such as maize and soybean, because it reduces flood-induced crop losses in flood-prone areas. Furthermore, cultivation of aerobic rice provides higher income compared to popular aerobic crops. The net returns of aerobic rice is higher than that of maize or soybean (Bayot and Templeton, 2009) when aerobic rice yields of 4,465 lb/acre or more are achieved, and this is a major reason why farmers choose to replace traditional crops with aerobic rice.

Regional differences in aerobic and irrigated rice growing areas make it difficult for a universal comparison of the two systems. Lower yield may pose a barrier for farmers to adopt aerobic rice farming systems. Hence, breeding high yielding aerobic rice varieties is an important aspect in minimizing the economic disadvantages associated with aerobic rice farming.

Selecting for Aerobic Rice

Weeds are the greatest yield-limiting constraint to aerobic rice and are able to reduce grain yield by 50% (WARDA, 1996). Hence, aerobic rice varieties have to be selected for high weed-competitiveness, in addition to being selected for high grain yield (Zhao et al, 2006a). In a 3-year experiment, weed-competitive traits (crop vigor, canopy ground cover, height, tillers per plant, vegetative crop biomass, and plant erectness) were negatively correlated with weed biomass across years (Zhao et al., 2006b). Fast early growth is an important trait of the weed-suppressive

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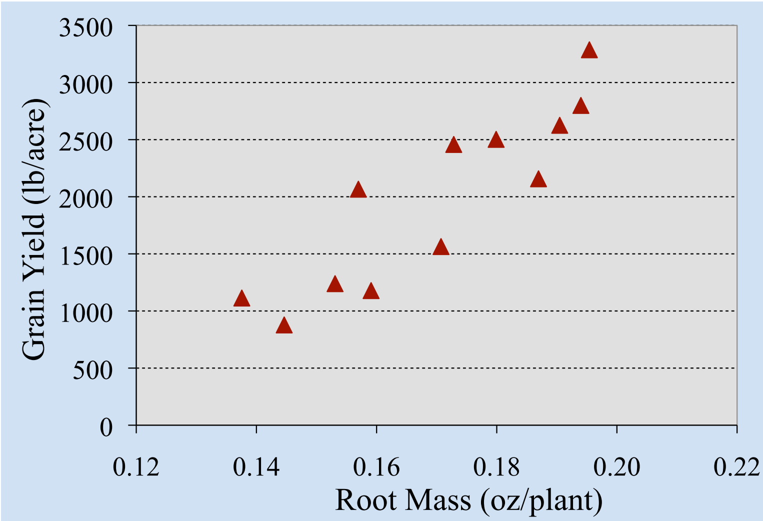

Fig. 1. Positive relationship between root mass at flowering and grain yield in irrigated aerobic rice culture in India (Graphed from data presented in James Martin et al., 2007).

aerobic rice varieties, and it must be selected for especially in breeding for tropical japonica rice, which has fewer tillers and lower weed suppressing ability than indica rice. Rice varieties grown in the U.S. are of the tropical japonica group. Although aerobic rice is not being bred for at the Texas A&M University System, AgriLife Research and Extension Center at Beaumont, TX, one of the selection criteria in its rice breeding projects is the selection for a faster growth rate. This is selected by visually rating thousands of breeding lines in both the pedigree and observational nurseries against a check variety (Cocodrie) during the early tillering stage and identifying the lines that have higher tiller density and larger leaf area. It would be interesting to determine performance of these fast growing lines under irrigated aerobic rice conditions.

In an aerobic rice field experiment conducted at India, James Martin et al. (2007) evaluated 12 rice varieties for several traits at flowering (leaf area, root length, volume, and mass, and plant mass) and harvest (number of panicles per m^2, number of filled grain per panicle, and grain yield), amount of irrigation and total water used, and water use efficiency (WUE). When data results from their study were analyzed, it was determined that grain yield and WUE were highly correlated at r = 0.98 (Table 1). Furthermore, the following traits were positively correlated with grain yield: root dry mass (r = 0.89), plant mass (r = 0.88), number of filled grain per panicle (r = 0.85), panicle density (r = 0.85), leaf area index (r = 0.44), root length (r = 0.31), and root volume (r = 0.16). High correlation coefficients for these traits suggest they should be targeted in the selection and breeding of high yielding and high WUE aerobic rice. This analysis also discriminates that it is root mass (Fig. 1), rather than root length or volume that is more important in increasing grain yield and WUE.

Currently, research and breeding for aerobic rice is a component of breeding programs in several research sites, including the International Rice Research Institute and the African Rice Center. Continuous research on aerobic rice to improve yield is necessary to increase its economic viability globally.

Table 2. Production cost estimate showing the savings in irrigation costs of aerobic rice.

Cost Item	Base Case (Irrigated Rice) Irrigation Cost		Aerobic Rice Irrigation Cost Saving (53%)	
	At Low Irrigation Costs	At High Irrigation Costs	At Low Irrigation Costs	At High Irrigation Costs
Irrigation cost	$38.00	$120.00	$38.00	$120.00
Irrigation cost saving	-	-	$20.14	$63.60
Production cost[1]	$982.99	1,064.99	$962.85	$1,001.39

[1] Cost of production of main and ratoon crops, excluding irrigation costs is $944.99 (Falconer, 2008).

Application of Knowledge to Texas Rice

An analysis was conducted to evaluate the potential for aerobic rice in Texas. Table 2 provides the irrigation cost savings

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Table 3. Comparison of net benefits in irrigated and aerobic rice under different irrigation cost scenarios.

Yield Scenario	Grain Yield (lb/acre)	Price/lb	Gross Benefits[1]	Net Benefits[2]	
				At Low Irrigation Costs	At High Irrigation Costs
Irrigated Rice					
Average Lower 10%	2,763	$0.16	$453.13	-$529.86	-$611.86
Mean	7,240	$0.16	$1,187.36	$204.37	$122.37
Average Upper 10%	10,804	$0.16	$1,771.86	$788.87	$706.87
Aerobic Rice (showing 32% yield reduction)					
Lower 10%	1,879	$0.16	$308.13	-$654.72	-$693.26
Mean	4,923	$0.16	$807.40	-$155.45	-$193.99
Upper 10%	7,347	$0.16	$1,204.86	$242.01	$203.47

[1] Gross benefit = yield x price

[2] Net benefit = gross benefit - production cost. Production costs were estimated in Table 2.

under low ($38/acre) and high ($120/acre) irrigation cost scenarios, based on using the irrigation costs presented herein and the remaining fixed and variable cost estimates from Falconer (2008). In aerobic rice, production costs of the combined main and ratoon crops were estimated to be $963/acre and $1,001/acre for the low and high irrigation cost scenarios, respectively. In estimating net benefits, three yield scenarios were considered – low, average, and high. Based on the 2008 main and ratoon crops yield data on conventional long-grain irrigated rice production that was estimated from the Texas Rice Crop Survey (Texas AgriLife Research and Extension Center at Beaumont, 2008), the average of the lowest 10% of rice yields was 2,763 lb/acre, the mean of all rice yields was 7,240 lb/acre, and the average of the highest 10% of rice yields was 10,804 lb/acre. The average price of long grain rice in 2008 ($16.40/cwt) obtained from the USDA Economic Research Service, (2009) was used in the analysis. Table 3 provides a comparison of estimated net benefits of lowland and aerobic rice. Under a low irrigation cost situation ($38/acre), net benefits of conventional irrigated rice varied from -$530 to $789/acre under different yield scenarios, while for aerobic rice, the estimated net benefits varied from -$655 to $242/acre (Table 3, Fig. 2). Under a high irrigation cost situation ($120/acre), estimated net benefits of conventional flooded rice varied from -$612 to $707/acre under different yield scenarios, while for aerobic rice, the net benefit could vary from -$693 to $205/acre (Table 3, Fig. 3). These results indicated that aerobic rice production would not be economical in Texas with existing varieties and the current rice cost and benefit structure. Although aerobic rice would save water, the reduced yield would more than offset any advantages. Water would have to be much more expensive for aerobic rice production to be economical in the U.S.

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Fig. 2a

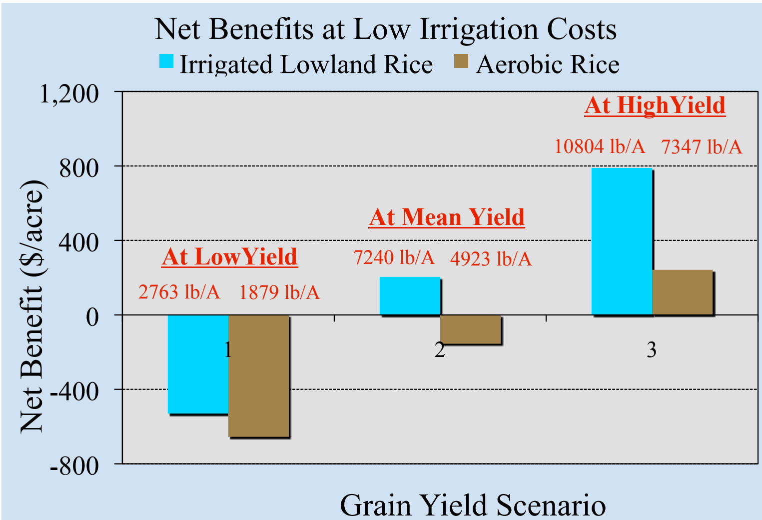

Fig. 2b

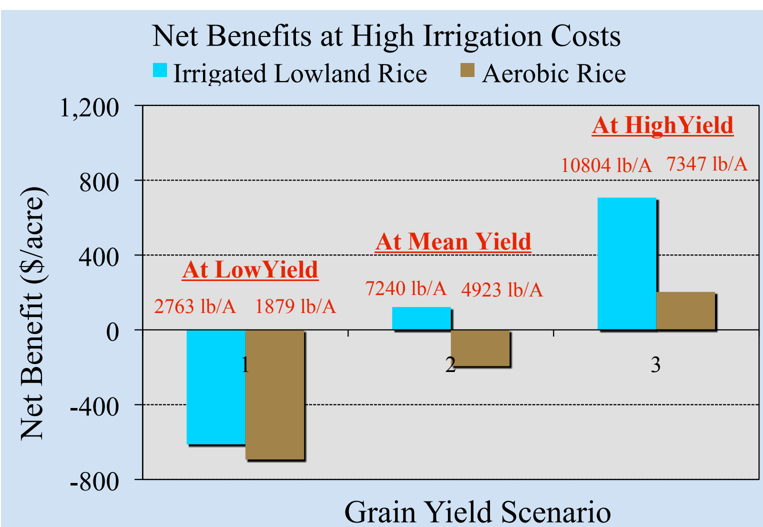

Fig. 2. Comparison of estimated net benefits between irrigated lowland rice and aerobic rice at three yield levels at (a) low irrigation costs ($38/acre) and (b) at high irrigation cost ($120/acre). Yields were estimated from the raw data of the Texas Rice Crop Survey in 2008 (Texas AgriLife Research and Extension Center at Beaumont, 2008). Price of long-grain rice was $16.40/cwt in 2008 (USDA Economic Research Service, 2009).

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* Article by Drs. Prabodh Illukpitiya, Stanley Omar PB. Samonte, and Lloyd T. Wilson. Texas AgriLife Research and Extension Center, Texas A&M University System, Beaumont, TX.

From the Editor ...

such as China and India, begin to see themselves as soon seriously bumping up against production barriers caused by ever-increasing populations, the barrier to transgenic rice production will be lifted. Once the transgene gate is lifted for rice, we will also see broad-scale commercial production of transgenic biofortified rice.

Please keep on sending us your suggestions.

Sincerely,

L.T. Wilson
Professor & Center Director
Jack B. Wendt Endowed
Chair in Rice Research

Rice Crop Update

As of August 28, 2009, 100% of the rice acreage in Texas had passed the heading stage, and 67% had had been harvested for their main crop grain yield (Fig. 1). About 4% of the rice acreage had been harvested for its ratoon crop grain yield.

Weekly updates on the acreage and percentage of rice grown in Texas that are in the various growth stages are available at our website at http://beaumont.tamu.edu/CropSurvey/CropSurveyReport.aspx.

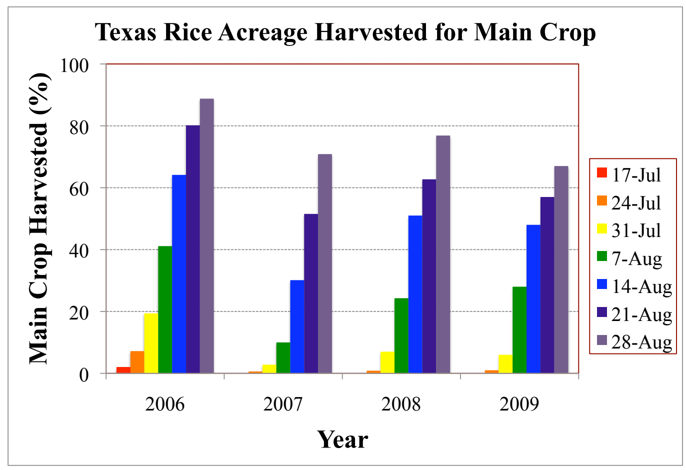

Fig. 1. Percentage of Texas rice acreage, on a weekly basis, that had been harvested for their main crop grain yield in 2006 thru 2009.

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