Nitrogen and Rice, and its Research at Texas AgriLife

Nitrogen and Rice

Nitrogen is one of the 16 essential nutrients of plants. It is a major component of the photosynthetic apparatus, from which green plants, including rice, depending on for supply of reduced carbon (such as carbohydrates), reduced N compounds (such as amino acids), and most of their organic chemicals used as food or building-block compounds. The sugars and amino acids are sometimes called the currency of the plant because they are the main forms distributed throughout the plant where they enter into a plethora of uses. Rubisco or ribulose-1,5-bisphosphate carboxylase/oxygenase or rubisco, an enzyme which catalyzes carbon fixation during photosynthesis, is the world’s most common protein and nearly all life depends on photosynthesis directly or indirectly. Rice leaves have among the highest rubisco concentrations observed in crop plants. Nitrogen is present in high concentrations in rubisco, which also serves as a major storage form for N in plants and is readily broken down in the leaf to provide amino acids for use in various parts of the plant [1].

In rice plants, N is required during the vegetative stage to promote growth and tillering, which in turn determines the potential number of panicles [2]. Nitrogen also contributes to spikelet production during the early panicle formation stage, and contributes to sink size by decreasing the number of degenerated spikelets and increasing hull size during the late panicle formation stage. Furthermore, N contributes to the accumulation of carbohydrates in culms and leaf sheaths during the preheading stage and in grain during the grain-filling stage by being a component of photosynthesis [2].

Nitrogen Cycle

Nitrogen is the nutrient element most limiting to crop production and it is the

Fig. 1. Nitrogen cycle in an irrigated rice culture system.

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Welcome to the May issue of Texas Rice. Rice planting is largely completed, with a considerable amount of late planted rice. Increased global prices have done a lot to booster grower sentiments and increase the amount of acreage planted late in the season. Rice acreage in Texas this year is probably somewhere near 170,000 acres. On a less positive note, with all the late planting this year, we don’t have a good handle on the amount of rice acreage that went in this year. Hopefully, we will have a better figures in a couple of weeks. Also on a negative note, I understand many of our Western ricebelt counties maxed-out on above ground water supplies. Had water been available, rice acreage would undoubtedly have been higher.

The last four weeks have seen me travel to College Station to participate in an administrative review of the Center, to the University of Arkansas to attend a Rice Processing Program Industry Alliance Meeting hosted by Terry Siebenmorgen, involving rice millers, food processor, seed companies, research scientists, and others, to Manhattan, Kansas to attend a post-harvest insect rice grain management meeting hosted by Frank Arthur, with scientists from Arkansas State University, the University of Arkansas, Texas A&M University, Louisiana State University, Oklahoma State University, and the USDA-ARS Post-Harvest Grain Management Laboratory in Manhattan, Kansas, and back to College Station, to attend meetings with CERES and a company called AFE to discuss the use of physiological-based crop modeling in strategic and tactical management of energy cane, high biomass sorghum, switchgrass, and forage rice for cellulosic bioenergy crop production. It is truly satisfying to see all of the great collaboration going on between our researchers at Beaumont and Eagle Lake, researchers in these other states, and with other institutions and companies.

Forage rice, the last crop mentioned in the previous paragraph, is probably something that most of you are not familiar with. Forage rice breeding is a very new part of what we do at Beaumont, a part that complements well our conventional rice breeding program. You can view forage rice as the outcome of a rice breeding program, with the goal being to maximize vegetative mass and not grain mass. Rice plant breeders have historically selected for plant types that are short in stature, to minimize the likelihood of the plants lodging (falling over), that produce either large panicles or a greater number of panicles, to increase grain yield, that have a high ratio of grain mass to total above ground plant mass, referred to as a high harvest index, and that mature more quickly, in part to avoid lodging due to late season winds. In contrast, forage rice plant breeding selects for plant types that are tall, to increase above ground biomass, that produce smaller panicles to allow energy to continue to go into new leaf and stem mass that can support an even bigger plant, and that have a low ratio of grain mass to total above ground plant mass, in this case resulting in a low grain harvest index. Because forage rice has smaller panicles, it does not lodge. Because the goal of forage rice breeding is the maximization of biomass production, the genetic lines that have historically been discarded as part of conventional rice breeding program, have now become a potentially valuable commodity. Had we kept a repository of the low grain yielding selections that were weeded out during previous selections, we would probably be much further down the road in developing a valuable feedstock for the emerging cellulosic bioenergy industry.

One more comment regarding forage rice. During...
High Nitrogen Utilization Efficiency Rice Lines

Nitrogen is very important in crop production and is considered as one of the most essential components of modern agriculture. However, it is the most expensive among the production inputs. The current supply shortages and soaring prices of fertilizer is a big threat to the production gains made by modern farmers throughout the world. The high demand for fertilizer is driven by several inter-related events, including population growth, China’s expanding economy and associated escalating demand for petroleum products, shrinking world grain stocks, and to a much smaller degree the increasing demand for corn and other crops to make biofuels. These events have tripled the price of fertilizers in the past year.

Applying higher amounts of N fertilizer can increase the concentration of N in rice plants, but this does not always increase grain yield due to diminishing returns, and it is not always optimal from an economic perspective. Application of too much N is not only cost-ineffective, but also harmful. The excessive use of N poses potential adverse environmental and health concerns [1], and increases the incidence of foliar pathogens and plant lodging. Being expensive and potentially damaging to the environment, N applied should be efficiently used by the plants. Rice, like other crops, has variations in its ability to use the supplied nitrogen. N utilization efficiency (NUE), the ratio of grain yield (lb grain) to N uptake (lb N), has been reported to vary significantly among lines at tropical [2], subtropical [3], Mediterranean [4], and Texan environments [5]. In a study conducted at the Texas AgriLife Research and Extension Center at Beaumont, estimates of NUE values obtained from diverse rice lines ranged from 25.3 to 63.9 lb grain/lb N [5]. Its importance is apparent when a comparison is made between lines with non-significantly different grain yields, but with significantly different N contents. The line with the relatively lower N content has a higher NUE, indicating that it produces the same amount of grain from less amount of N.

Many desirable traits are bred into rice cultivars before they are released, but only a few breeding

![Fig. 1. High panicle NUE values of selected entries in a Beaumont yield trial in 2007, relative to that of Cocodrie.](image-url)
High NUE Rice continued ...

programs are using high NUE as one of the selection criteria in the goal of producing rice cultivars that efficiently utilize the N applied. Currently, high NUE is one of the selection criteria with which rice lines in the breeding program at the Texas AgriLife Research and Extension Center at Beaumont, TX, are being evaluated and selected. The use of NUE as one of selection criteria started in 2005. Elite lines that are entered into yield trials are also evaluated for their NUE values. Plant samples are obtained from selected entries at heading and at harvest, and the N content of these samples are determined. Grain yield is estimated from the plant samples that were obtained at harvest. The NUE of each elite line is then estimated using the grain yield and N content values. For each line, the N content that is higher is the one used in the estimation of NUE, since it is a better estimate of the total amount of N absorbed.

Last year, the range of panicle NUE of selected rice lines entered into yield trials ranged from 17.7 to 49.6 lb panicle/ lb N, with an averaged of 38.0 lb panicle/ lb N. Twenty of the 36 rice lines evaluated had higher panicle NUE than Cocodrie, which had a panicle NUE of 37.8 lb panicle/ lb N. Figure 1 shows the top 10 rice entries ranked for high panicle NUE compared to Cocodrie.

This year, 37 of the high yielding rice lines that are entered in the yield trials of the rice varietal development project funded by the Lower Colorado River Authority and San Antonio Water Systems will be sampled for grain yield and plant N content, and their respective NUE values will be estimated. Lines that have relatively higher NUE values and higher yield, compared to the check cultivar Cocodrie, are more desirable than those that do not. In the previous years, panicle NUE (lb panicle/lb N absorbed) results have helped in selecting the rice lines that will be dropped from a specific yield trial, retained in the trial for further testing, or advanced to the next level of yield trials.

For more information, please consult the following references:


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most demanding of management skills. The nitrogen cycle (Figure 1) of an irrigated rice culture system has pathways through which ammonium and nitrate, forms of N that the plant takes up, are increased in the soil through mineralization and fertilization. The N in soil organic matter is unavailable to higher plants and it has to be transformed to ammonium or nitrate before the plant takes it up. Ammonium enters directly into the biosyntheses of amino acids and other compounds, while nitrate must first be reduced to the ammonium level thru nitrate reduction using the energy and reducing power supplied through respiration.

The N cycle also has the pathways through which N is lost (denitrification, volatilization, leaching, surface run-off, uptake by weeds, foliar loss). In flooded rice, a thin layer of the soil is aerated by...
dissolved $O_2$; mineralization (release of ammonium and ammonia from organic forms) and nitrification (oxidation of ammonium to nitrate) are favored in this region. Ammonium ions are immobile (strongly absorbed by soil colloids), while nitrate ions are mobile and move with water drainage. The nitrate leaches due to nitrate diffusion and water flux into the anaerobic zone, which is most of the soil profile, where it is denitrified. Denitrification, the conversion of nitrate to gaseous $N_2O$ or $N_2$ by a variety of bacteria ($Alcaligenes$ and $Pseudomonas$), is the major pathway through which N returns to the atmosphere. Anaerobic environments, such as heavy soils with poor drainage (e.g. flooded rice) or well-drained soils during brief periods of water saturation, favor denitrification. Because of this, N is supplied to rice crops through use of an ammonium fertilizer placed in the reducing zone where nitrification is inhibited. Urea and ammonium sulfate are the most commonly used sources of N in rice production, and there are no significant differences between these N sources on dry matter and total N accumulation at heading and at maturity of drill-seeded lowland rice [3].

Nitrogen management primarily involves the reduction of N losses and the improvement of N uptake efficiency to produce a rice crop of high grain yield and quality. These can be achieved by appropriate fertilization (type, amount, timing, and placement), cultivar selection (high harvest index or high N utilization efficiency), and weed and water management.

**Recommended N Fertilization Amounts**

In Texas, N fertilizer amounts are recommended based on the rice-growing region (Western or Eastern Rice Belt) and soil texture (fine or coarse). Based on the annual rice production guidelines that are produced by Texas AgriLife, the general recommended amount for N fertilization in 1976 averaged 97 lb/acre for cultivars that included Labelle, Lebonnet, Bluebelle, Brazos, Nato, and Vista [4]. In 1988, the average N recommendation was 158 lb/acre for semi-dwarf long grain cultivars (Lemont, Gulfmont, and Rexmont) and 112 lb/acre for conventional long grains cultivars (Labelle, Lebonnet, Skybonnet, Newbonnet, and Tebonnet) [5]. Furthermore, the N fertilizer was split into three applications (at planting, just before permanent flood, and at panicle differentiation). This split application is still being practiced. In 1998, the general recommendations were 170 lb/acre N for fine soils and 150 lb/acre for coarse soils [6]. At present, Dr. Lee Tarpley and Mike Jund [7] recommend N fertilizer rates for long-grain inbred and hybrid cultivars for fine and coarse soils in the Western and Eastern rice belts. The N-fertilizer rates for inbred cultivars are mostly 170 lb/acre for fine soils and 150 lb/acre for coarse soils.

Dr. Tarpley has been evaluating the effect of increasing the amount of N applied to hybrid cultivars. Currently, hybrid cultivars have the highest yield potential among cultivars for the mid-south US. Yet, studies conducted in Texas and Mississippi indicate their yield is limited by current N fertilization rates, at least on the clay soils. There is a significant increase in the grain yield of XL723 when the amount of N applied is increased from 160 to 225 lb/acre N. Fertilizing with more N increases the risk of lodging, so the use of a plant growth retardant (Palisade [Syngenta]) applied about 14 days after panicle differentiation is also being evaluated to decrease final plant height and the risk of lodging [8].

**Nitrogen Stress**

It is commonly recommended that N be applied immediately upon observing N deficiency symptoms in a rice field, since each day that the fertilization is delayed causes a further decrease in grain yield. Some symptoms or observations that indicate N deficiency in a rice field include: darker green rice plants on the levees compared to the rice between levees; dark green plants in some areas and light green plants in other areas; young (or upper) leaves that are green with yellow tips, while older (or lower) leaves are yellowish with brown tips; and a low chlorophyll reading. A chlorophyll meter is used to estimate the nitrogen status of the rice plant since the green color of leaves as perceived by the human eye varies with the time of day and amount of sunlight. Texas AgriLife researchers determined that adding N when the chlorophyll reading is above 40 for rice cultivars Presidio, 39 for CL161, Cocodrie and Cybonnet, or

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38 for Trenasse does not commonly provide yield benefits [7]. There is also a leaf color chart, which simulates six shades of green rice leaves. There is no need to apply N fertilizer when the color of the majority of the leaves is similar to any of the three darker shades of green [9]. Figure 2 shows the chlorophyll meter and a color chart reading of a rice leaf.

In contrast to N deficiency, if a rice field has not been cropped recently or has a history of severe lodging, then there may be a need to reduce the amount of N applied as fertilizer.

**Fertilization Methods and N Uptake Efficiency**

In the drill-seeded rice fields across of the southern U.S., the N fertilizer that is applied varies in amount and timing. Furthermore, the total amount of N is split into about two to five applications depending on individual producer management. Producers sometimes use multiple aerial applications of N to improve N uptake efficiency and yield compared to only one application. Nitrogen uptake efficiency is the ratio of the amount of N taken up by the plant over the amount of N applied as fertilizer. Dry granular urea is sometimes broadcast onto the dry soil surface and incorporated when applied pre-plant or washed into the dry soil by irrigation water when applied pre-flood. An undesirable scenario would be the broadcasting of urea onto wet soil, which reduces N uptake efficiency since subsequent flood irrigation can not effectively wash the applied N deep enough into the soil to avoid the oxidized layer at the soil surface. Urea that is on the surface or oxidized layer will be lost thru denitrification upon flooding.

**Fluid Fertilizers**

Nitrogen uptake efficiency is also affected by the state of the N fertilizer applied. For example, N uptake efficiency has been improved by subsurface banding of N fertilizers and by subsurface application of aqueous ammonia. At the Texas AgriLife Research and Extension Center at Beaumont, a study was conducted to determine if a combination of fluid fertilizer and early floodwater establishment could reduce fertilizer and application inputs or increase rice yields by maximizing N efficiency. Dr. Fred Turner, Mr. Jund, and Dr. Tarpley [10] compared the N uptake and grain yields of rice treated with either subsurface-banded fluid fertilizer (Figure 3) or broadcasted dry granular urea applied in 1, 2, or 3 split applications. Two floodwater irrigation treatments were applied: early

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(4-leaf stage) and conventional (6-leaf stage). This field-plot research was conducted on clay soil in 2003 and clay and silt loam soils in 2004. Higher N uptake was observed in the fluid-fertilizer treatment applied during planting compared to that of broadcasted dry granular urea in both flooding regimes (flooding at 4- or 6-leaf stage) in 2003 and in both soil types in 2004. Fluid fertilizer also increased yield in both soil types in 2004, and in the conventionally flooded treatment in 2003. Since rice grain yields were as high as those obtained from split applications, the findings suggested that the single application of subsurface-banded fertilizer at planting can help reduce or eliminate subsequent N applications [10].

**Timing of Fertilization**

The uptake of N by the rice plant varies with year, soil type, and water management. It also varies depending on the time of N application. In a study conducted at the Texas AgriLife Research and Extension Center at Beaumont, the N uptake efficiency of rice plants was determined for different N application times during the growth of the plant. The study conducted by Dr. Tarpley, Mr. Jund, and Dr. Turner determined the application timings during which N is most efficiently used by rice plants. Nitrogen uptake efficiency of the rice plant was estimated after the application of 50 lbs of enriched N (15N) at: 1) pre-plant, 2) three-leaf stage, 3) pre-flood on dry soil, 4) one day after flooding, 5) one and ten days after flooding (N was applied in split 50:50), 6) panicle differentiation (PD), 7) early PD and PD (N was applied in split 50:50), and 8) PD and late PD (N was applied in split 50:50).

Figure 4 shows the N uptake efficiencies of different N application timings, averaged across two years of study on clay soil at Beaumont and one year on sandy soil at Eagle Lake. The figure shows that the application of N at the 3-leaf stage rather than at pre-plant may reduce the total N application rate. It also shows that applying N pre-flood on dry soil was 1.6 times more efficient than applying within 10 days after flooding, even if the post-flood N application was split into two. Furthermore, applying N at PD, after the roots have formed on the soil surface, was more efficient than early or late split application near the PD stage [11].

![Fig. 4. Nitrogen uptake efficiency at different applications times during the rice crop’s life cycle [11].](image-url)

**Water Management**

Normal, delayed, and flush irrigation do not result in rice plants differing in their tissue N concentration (although they may differ in the amount of weed pressure). However, although nitrogen is taken up most rapidly between the active tillering and booting stages for all three irrigation procedures, the N uptake was greater in the normal flooded than in flush irrigation during the panicle initiation to booting period and booting stages [12]. Since tissue N concentrations for all irrigation procedures were similar, the lower
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N uptake in rice plants subjected to flush irrigation is attributed to its lower shoot dry matter production [12] rather than soil N deficiency.

For the past few years, Dr. Ted Wilson and Mr. James Medley have been experimentally comparing conventional flood irrigation and sub-surface drip irrigation at the Texas AgriLife Research and Extension Center at Beaumont, TX. Small-scale experiments were conducted in 2001 to 2003, while large-scale experiments were conducted in 2006 and 2007. Although the primary objective was to compare the effects of different irrigation systems on grain yield, they were also able to evaluate the application of N (urea) through subsurface drip irrigation. The first fertilization (50 lb/acre N) was aerially applied at planting, while about 1 to 6 lb/acre/day N was applied three times a week, during the period between 30 days after emergence and panicle differentiation, until a total of 200 lb/acre N was applied. In 2006, the grain yield of rice plants situated over the irrigation tape (7,373 lb/acre) was significantly higher than that for flood irrigation (6,285 lb/acre), but the yield between tapes was significantly lower than that for flood irrigation (Figure 5). However, in total, the rice treated with subsurface drip irrigation was not significantly different in grain yield compared to that of the flood irrigation [13]. Based on observations they made in 2006, a modification in the fertilization procedure was done in the 2007 irrigation experiment, that is, 0.3 inch of water was applied during each N application thru sub-surface drip irrigation in order to spread the urea to a mid-point between the tapes. A third large-scale subsurface drip irrigation experiment is currently being conducted this 2008 cropping season.

For more information, please consult the following references:


the meeting with CERES, which is a plant biotechnology company, I was asked what role I thought forage rice would play in the evolving cellulosic bioenergy industry. Dr. Rodante Tabien recently demonstrated that an early high-biomass selection of one of his forage rice lines produced 1,000 lbs/ac dry weight when harvested in mid-July. With such an early harvest date, it is quite conceivable that a second and possibly a third harvest would be possible. Biomass yields of 50,000 to 60,000 lbs per acre during a single season would compete with all but the very best energy cane fields. In heavy soils, where rice grows well, forage rice may have a very strong future. For the Upper Gulf Coast region of Texas, my bet is that 15% or more of bioenergy crop production could be planted to forage rice. With relatively minor changes to existing combines, so the straw can be caught instead of chopped and spread, forage rice could be grown with existing equipment. The real question is when will the Upper Gulf Coast’s bioenergy industry really take off. Our scientists are working hard to insure we can delivery viable bioenergy crops, be it energy cane, high biomass sorghum, forage rice, or switchgrass, and production and management programs that will allow growers to maximize the production efficiency of these new crop systems.

June and July are busy months for the Texas AgriLife Research and Extension Center at Beaumont and the David R. Winterman Rice Station at Eagle Lake. More will be written about our Field Days during the soon to be released June issue of Texas Rice. In addition to our upcoming Eagle Lake and Beaumont Field Days (scheduled for June 24 and July 10, respectively), we have two additional meetings that are coming up shortly. On June 16 and 17, presentations will be given on the 2008 Farm Bill. The following information describes the focus and location and timing details for each meeting.

USA Rice Federation will provide industry members with an overview and explanation of the key provisions of the Food, Conservation and Energy Act of 2008 (2008 Farm Bill) at two local educational meetings scheduled June 16 and 17 in Texas. The meetings will allow rice producers, landowners, other industry members and allied businesses to get answers to questions they have about the new farm bill and rice-specific provisions.

The first meeting will be held on Monday, June 16 from 3:00 – 5:00 p.m. at the El Campo Civic Center (Duson Room), 2450 N. Mechanic Street, El Campo, TX.

On Tuesday, June 17, from 1:00 – 3:00 p.m., USA Rice will conduct a meeting at the Texas AgriLife Research and Extension Center Administration Building in the AgriLife Auditorium and Conference Room, 1509 Aggie Drive, Beaumont, TX.

All rice industry members and others involved in agriculture are encouraged to attend one of these meetings.

If you have any questions about the meetings, please contact either Reece Langley, (703) 839-5297, or Randy Jemison, (337) 738-7009.

Please keep on sending us your suggestions.

Sincerely,

L.T. Wilson
Professor and Center Director
Jack B. Wendt Endowed Chair in Rice Research
Rice Crop Update

As of May 30, 2008, about 100% of the Texas rice acreage had been planted, 95% had emerged seedlings, 60% were at permanent flood stage, and 10% had reached panicle differentiation.

Texas Rice Acreage Planted

Texas Rice Acreage at Permanent Flood

Texas Rice Acreage with Emerged Seedling

Texas Rice Acreage at Panicle Differentiation

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