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Rice Fertilization

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Introduction

Since 1998, rice (*Oryza sativa* L.) production has averaged approximately 265,000 acres per year in Mississippi. Average rice yields have increased from 5,800 pounds per acre in 1998 to a record 6,500 pounds per acre in 2001. Had it not been for 25% of the rice crop being unharvested prior to the onset of high winds and rain as a result of the tropical storms, a new yield record may have been reached in 2002. Among many factors that have helped to improve average rice yields, the implementation of higher yielding cultivars and better fertilizer management are the most notable.

A cultivar's yield potential is strongly related to nutrient management. Cultivars can differ on nitrogen (N) rate and application timing requirements. In addition to N, it is imperative to manage phosphorus (P), potassium (K), sulfur (S), and micronutrients so that a proper balance is maintained. This report outlines the importance of each of the major nutrients needed to maximize rice grain yields, gives recommendations on the proper rate and application timing, and describes in detail the common nutrient deficiency symptoms that will occur in rice.

Nitrogen

Nitrogen is the most limiting nutrient for rice production in the southern United States (Helms and Slaton, 1996; Linscombe et al., 1999; Miller and Street, 2000). Unlike nutrients such as P, K, and zinc (Zn), no suitable soil test method has been established and implemented for determining the N-supplying capacity for soils used to produce rice (Dobermann and Fairhurst, 2000). Instead, numerous N rate and application timing studies are conducted on experiment stations and farms to determine the optimum N rate by application timing for the various cultivars that are grown in the rice-producing states. Most of the rice in Mississippi is produced in a dry-seeded, delayed flood cultural system in which the permanent flood is not established until the rice is 6 to 8 inches tall. In the southern United States, optimum N fertilizer use efficiency has been achieved by applying at least 50% of the total N immediately prior to permanent flood establishment, and the remaining N applied within the interval beginning with internode movement to 10 days after internode movement of 0.5 inch (Wilson, et al., 1998). However, recent work in Arkansas has shown that some new cultivars produce yields that are comparable, and sometimes greater, when a single preflood (PF) application is made as opposed to a two- or three-way split of the total applied N (Norman, et al., 2000). Rate and timing of N are critical in terms of their effect on yield. Nitrogen increases plant height, panicle number, leaf size, spikelet number, and number of filled spikelets (Dobermann and Fairhurst, 2000), which largely determine the yield capacity of a rice plant. Panicle number is largely influenced by the number of tillers that develop during the vegetative stage (DeDatta, 1981). Spikelet number and number of filled spikelets are largely determined in the reproductive stage (DeDatta, 1981). Overfertilization, underfertilization, and improper fertilization timing have the potential to decrease rice yields. Hence,

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it is important to determine the optimum rate and proper application timing of N fertilizers for individual rice cultivars.

In Mississippi, N fertility management is confounded by the widespread adoption of precision land leveling for irrigation purposes, the inability to establish and maintain a permanent flood within 5 to 7 days after fertilizer application, and high-pH soil conditions. Land forming in some areas requires the removal of the topsoil, which contains the highest percentage of organic matter. Less fertile subsoil is exposed and becomes the rooting media for the following rice crop. Thus, the organic fraction of the soil N-pool is often greatly decreased (Walker, 2002). The inability to establish and maintain a flood in a timely manner increases the likelihood of N losses through volatilization and denitrification once the flood is established. High-pH soil conditions increase volatility when urea (46-0-0) is used as the N-source (Tisdale et al., 1985). Each of these factors should be considered when creating an N budget. The source of N can increase N efficiency under certain situations. On newly precision-leveled fields, or on low-organic-matter soils, ammonium sulfate (21-0-0-24) may offer a yield benefit when compared with urea. Ammonium sulfate is also less volatile on high-pH soils compared with urea.

Table 1. Nitrogen Recommendations by Cultivar and Soil Type.

Cultivar	Clay soils				Silt loam soils[1]			
	Total	Preflood	Midseason		Total	Preflood	Midseason	
			First	Second			First	Second
	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A
Cocodrie	180	120	60	–	160	115	45	–
CL-121	180	120	60	–	160	115	45	–
CL-141	180	90	45	45	160	80	40	40
CL-161	180	120	60	–	160	105	45	–
Francis	180	90	45	45	160	80	40	40
Priscilla	180	120	60	–	160	115	45	–
Wells	180	90	45	45	160	80	40	40
XL7 [2]	180	120	60	–	150	90	60	–
XL8 [2]	180	120	60	–	150	90	60	–
CL-XL8 [2]	180	120	60	–	150	90	60	–

[1]For recently leveled silt loam soils (leveled within 5 years), apply the same rates as you would for clay soils.
[2]The midseason N application for RiceTec's hybrid varieties are applied in one application at booting to 5% headed.

In 2002, 'Cocodrie' was the predominate cultivar grown in the Mississippi Delta, occupying 68% of the rice acreage, followed by 'Priscilla' at 15%, 'Lemont' at 6%, and 'Wells' at 5%; 'Cypress,' 'CL121,' 'CL141,' and RiceTec's hybrids occupied the remaining acreage (Kanter et al., 2003). Table 1 gives the recommended N rate and application timing for the most commonly grown rice varieties in the Mississippi Delta. These recommendations were derived from numerous on-farm tests conducted on various soil types. CL141, 'Francis,' and Wells are susceptible to lodging. However, lodging can be reduced by applying 50% of the total N prior to establishing the permanent flood (PF), and splitting the remaining 50% into two midseason (MS) applications. For the other varieties that are not as sensitive to lodging, two-thirds of the total N should be applied PF. It is not necessary to split the remaining one-third at MS.

Phosphorus and Potassium

Phosphorus is very important in the early vegetative growth stages (Slaton et al., 2002). It is important to rice plants because it promotes tillering, root development, early flowering, and ripening. Rice plants that are deficient in P are stunted and dirty-dark green, and they have erect leaves, relatively few tillers, and decreased root mass (Dobermann and Fairhurst, 2000). Potassium increases the rice plant's tolerance to diseases and pests, and it may reduce lodging potential (Norman et al., 2002). Potassium-deficient plants are usually dark green with yellowish-brown leaf margins. Dark brown necrotic spots may occur on the tips of older leaves (Dobermann and Fairhurst, 2000). Potassium deficiencies will not usually occur until the later growth stages.

Most Delta soils are usually medium to high in P and K. A 150-bushel-per-acre rice crop removes 45 pounds of P_2O_5 and 24 pounds of K_2O per acre with the harvested grain (Fixen, 2001). However, because rice is predominantly grown in rotation with soybean, the fertility management should consider both crops. A 50-bushel-per-acre soybean crop removes 40 pounds of P_2O_5 and 70 pounds of K_2O per acre with the harvested grain (Fixen, 2001). Therefore, in a 1:1 rice/soybean rotation, approximately 85 pounds of P_2O_5 and 95 pounds of K_2O per acre are removed from the soil in a 2-year span. Depending on the soil type, the majority of these nutrients will be replenished by mineral weathering. However, to ensure that the current level of nutrients remains in the soil over an extended period of time, a maintenance application of P and K fertilizer equal to crop removal is recommended. As long as the soil is not deficient, the maintenance application can be made once per year or once per 2 years. As long as the crop does not require the application for optimum yields, the application timing for the maintenance application can be made in the fall or spring with equal results.

In the Mississippi Delta, rice P deficiencies are more widespread than K deficiencies. Phosphorus deficiencies usually occur in the cut areas and deep fill areas of coarse (lighter) textured soils, or on soils with low native P availability. If soil-test P levels fall into the medium to very low range, the Mississippi State University Soil Testing Laboratory recommends an application of 30 to 80 pounds of P_2O_5 per acre. When a P application is needed to optimize yields, the best results will occur if the P fertilizer is applied in a window that opens just before planting and closes just before the initiation of tillering.

Sulfur

Sulfur is important in the rice plant for chlorophyll production, protein synthesis, and carbohydrate metabolism (Dobermann and Fairhurst, 2000). Sulfur deficiencies will frequently occur in the cut and deep-fill areas of newly land-formed fields. Symptoms of S deficiency are very similar to N deficiency symptoms; however, the main difference is that sulfur is immobile in the plant. Therefore, the yellowing will first appear in new leaves rather than older leaves. Most soil sulfur is contained in the soil organic matter. Sulfur deficiencies on newly land-formed fields can usually be avoided by applying a minimum of 100 pounds of ammonium sulfate per acre between preplant and the two- to three-leaf plant stage. If additional sulfur is needed, a urea/ammonium sulfate blend (41-0-0-4) can be used as the N source preflood and at midseason, instead of urea.

Micronutrients

Micronutrient deficiencies typically do not occur on acid to slightly acid clay soils (pH = 5 to 6.5). However, silt and sandy loam soils, as well as any high-pH soils (>7.5), are subject to zinc (Zn) deficiencies. Soils with high available P and low organic matter are also subject to Zn deficiency (Dobermann and Fairhurst, 2000).

A Zn deficiency is expressed in one or more of the following ways in young seedling rice: (1) a bronzed appearance of the plants, and when closely examined the leaves often show an irregular rusty pattern; (2) drooping leaves and paleness; (3) pale-green color on the bottom half of the leaves 2 to 4 days after flooding; and (4) leaves become yellowish and start dying 3 to 7 days after flooding (Dobermann and Fairhurst, 2000). These deficiency symptoms are more severe in cold-water areas and where the flood is the deepest. If a soil test indicates a Zn deficiency prior to planting, apply 7 to 10 pounds of actual Zn (20 to 30 pounds of Zinc Sulfate) per acre. If deficiency symptoms occur after rice emergence, apply a zinc chelate at the rate of 0.5 to 1 pound of metallic Zn per acre as a foliar spray. Zinc chelate can be tank-mixed with propanil if the propanil is needed for weed control. If the deficiency does not occur until after permanent flood establishment, drain the field and allow the rice plants to recover before adding the zinc chelate.

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