Potassium Nutrition of Flood-Irrigated Rice

By N.A. Slaton, D. Dunn, and B. Pugh

Seasonal potassium (K) uptake pattern of flood-irrigated rice characterized on K-sufficient soils indicates that adequate K must be present during vegetative growth to maximize K uptake.

Our knowledge and understanding of the K nutritional requirements and K uptake trends for rice (*Oryza sativa* L.) are limited when compared to those of other essential macronutrients. The extensive, shallow root system of flood-irrigated rice…plus increased K availability after flooding… make rice an effective scavenger of soil K.

The importance of K fertilization for rice grown in the U.S. has only been realized during the past 15 years due to the annual occurrence of K deficiency in only a small percentage of commercial rice fields. The increased occurrence of K deficiency is attributed to higher rice and soybean yields and inadequate fertilization practices. For these reasons, research in the U.S. midsouth rice-growing area has focused on 1) characterizing rice K uptake and soil K availability during the growing season, 2) improving recommendations for diagnostic soil and plant analyses, and 3) evaluating K fertilization strategies. The following discussion is specific to K nutrition of drill-seeded rice grown on silt loams using the delayed flood management system (i.e., flooded at the 5-leaf stage, 20 to 30 days (d) after emergence, after urea is applied to a dry soil surface).

The majority of K fertilization trials show that maximum rice yields can be produced on soils with relatively low…80 to 100 parts per million (ppm)…soil test K (i.e., NH_4OAc or Mehlich-3 extraction). Significant yield increases from K fertilization seldom occur when soil test K is >80 ppm. Visual K deficiency symptoms [described in *Better Crops* 79(4):12-14] are usually expressed between panicle differentiation and heading, and are most likely to occur on silt and sandy loams with soil test K <50 to 60 ppm.

The K concentration of rice increases briefly after the permanent flood is applied at the 5-leaf stage and reflects the enhanced K availability in flooded soil. The K concentration of the whole-aboveground rice plant usually reaches its maximum concentration for the growing season during active tillering...2 to 4 weeks after flooding...and declines gradually for the remainder of the growing season. The K concentrations of individual leaves and stems are quite uniform during vegetative growth stages when tissue K concentrations are high (**Figure 1**). However, by the onset of reproductive growth, the whole-plant K concentration begins to decline and a K concentration gradient develops with the upper and middle leaves having greater K concentrations than the lower leaves. This concentration gradient between lower and upper leaves is most pronounced in K-deficient rice plants (**Figure 2**) and may range from 0.15 to 0.80%. Plant stems represent the majority of plant biomass and contain 50 to 75% of the aboveground K. Potassium concentrations in mature rice straw are usually >1.0% when K availability is not growth- or yield-limiting. Decreased tissue K concentration is due to dilution of plant K from rapid growth and limitations of the soil to replenish plant-available K during the season.

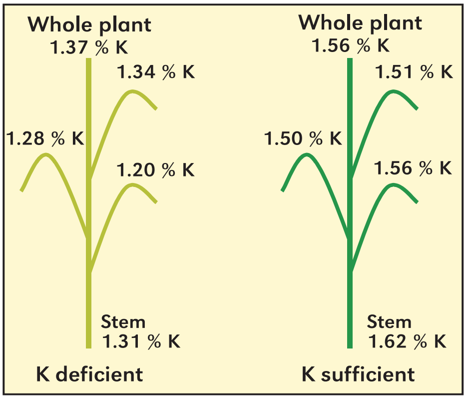

Figure 1. Potassium concentrations of the whole-plant, stem, and individual leaves shortly before panicle differentiation for K-deficient (unfertilized) and K-sufficient (fertilized) rice grown on a Crowley silt loam in Missouri in 2002.

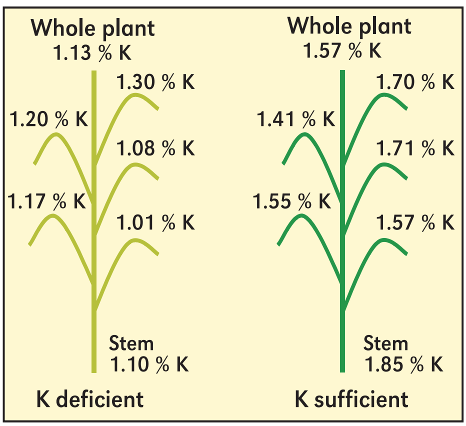

Figure 2. Potassium concentrations of the whole-plant, stem, and individual leaves at 10% heading for K-deficient (unfertilized) and K-sufficient (fertilized) rice plants grown on a Crowley silt loam in Missouri in 2002.

The crop growth rate of flood-irrigated rice managed in the direct-seeded, delayed-flood system is high (250 to 350 lb dry matter/A/day) shortly after flooding when adequate nitrogen (N) has been applied and other nutrients are not limiting (**Figure 3**). Although rice has a small, but rapidly developing, root system during the tillering stage, rice uptake of K is rapid. About 60 to 80% of the total K uptake occurs during the first 4 to 6 weeks (1,300 to 1,700 DD50 units) after flooding (**Figure 4**). Maximum K uptake rate occurs between 1 and 5 weeks after flooding, before panicle differentiation (**Figure 3**). The K uptake rate declines continuously for the remainder of the growing season (**Figure 4**) and is reflected by decreasing K concentrations in aboveground tissues. Early-season K fertilization has the greatest influence on K uptake and K uptake rates during vegetative growth (data not shown). The trends in K uptake suggest that soil and fertilizer K are absorbed rapidly and efficiently shortly after flooding. Late-season (i.e., boot stage) K applications applied into the floodwater appear to be absorbed less efficiently.

By anthesis, plant uptake of K has generally reached its season maximum and plateaus during grain fill (**Figure 4**). Although some studies show that net K uptake may increase or decrease slightly after anthesis, K uptake appears to be minimal or balanced with possible losses of K from sloughed plant tissues. Total (straw plus grain) aboveground K uptake by rice parallels total N uptake and usually ranges

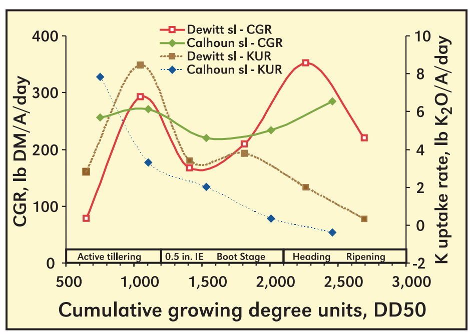

Figure 3. Postflood crop growth rates (CGR) and K uptake rates (KUR) of rice grown on a Dewitt and Calhoun silt loam in Arkansas during 2001. Each data point represents the rate of growth or K uptake for ~14 d periods (IE=internode elongation).

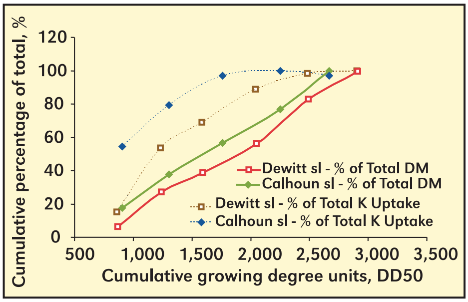

Figure 4. Cumulative dry matter accumulation and K uptake during the growing season by rice grown on a Dewitt and Calhoun silt loam in Arkansas during 2001. Each data point represents the rate of growth or K uptake for ~14 d periods.

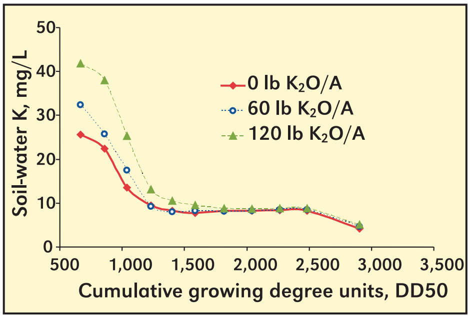

Figure 5. Postflood soil-water K concentrations as affected by K application rate for rice grown on a Dewitt silt loam soil in Arkansas during 2001. Each data point represents a 7- or 14-d interval.

from 150 to 250 lb K/A, with 10 to 15% of the total aboveground K removed with the harvested grain.

The concentration of K^+ in the soil water (soil solution of flooded soils), as well as soil test K, follow trends similar to the K concentration in rice tissues for the first few weeks after flooding. Soil-water K concentrations peak about one week after flooding, decline rapidly until 4 to 5 weeks after flooding, and then reach a consistently low concentration for the duration of the season (**Figure 5**). Soil-water K concentrations are increased by early-season K fertilization for only 3 or 4 weeks after flooding. Both soil K pools, exchangeable and solution, reach low K concentrations near the time of panicle differentiation and persist until the flood water is drained for harvest. The growth stage at which the soil K pools appear to be depleted on K-sufficient soils coincides with the general time that K-deficiency symptoms appear on K-deficient soils, as well as the time that rice tissue K concentrations and root uptake of soil K are declining. Silt loam soils apparently have a limited ability to replenish plant-available soil K during the season, which makes proper early-season K fertilization essential to avoid potential yield losses. Another possibility is that silt loam soils may be unable to retain plant-available soil K after extended flooding due to K losses via leaching, runoff, or fixation mediated by anaerobic soil conditions.

The seasonal K uptake pattern of flood-irrigated rice characterized on K-sufficient soils indicates that adequate K must be present during vegetative growth to maximize K uptake. Potassium absorbed during vegetative growth is mobilized within the plant to maintain the K nutritional status of new growth during reproductive growth. Routine soil testing and use of adequate K fertilizer rates before flooding are required to prevent K from limiting rice growth and yield. Because rice is usually rotated with upland crops such as soybean, which are more sensitive to K deficiency, K fertilization programs for rice should consider the K requirements of crops grown in rotation with rice. BC

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