Optimal nitrogen fertilization timing for upland rice

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Abstract

Nitrogen is one of the most yield limiting nutrients for upland rice production in South America, including Brazil. A greenhouse experiment was conducted to determine optimal nitrogen fertilization timing for upland rice grain yield and yield components. The total N applied was 300 mg/kg and N timing treatments were: T_1 (1/2 N applied at sowing + 1/2 applied at panicle initiation), T_2 (total N applied at sowing), T_3 (1/3 N applied at sowing + 1/3 N applied at active tillering + 1/3 N applied at the panicle initiation), T_4 (1/2 N applied at initiation of tillering + 1/2 N applied panicle initiation), and T_5 (2/3 N applied at sowing + 1/3 N applied at panicle initiation). Grain yield, shoot dry weight, panicle number, and grain harvest index were significantly influenced by N timing treatments. Maximum grain yield was obtained with one-third N applied at sowing + one-third applied at active tillering and remaining one-third applied at panicle initiation. Total N applied at sowing produced minimum grain yield, shoot dry weight, and panicle number. Shoot dry weight and panicle number were positively and significantly related to grain yield.

Key Words

Grain yield, grain harvest index, *Oryza sativa* L., yield components

Introduction

Rice is a staple food crop for more than 50% of the world population (Fageria *et al.* 2003). Upland rice is defined as the rice grown on undulated or flat well drained soils, without water accumulation in the field during crop growth cycle and totally depends on rainfall for water requirements. Upland rice is also known as aerobic rice is mainly grown in South America, Africa and Asia (Fageria 2002). In South America, upland rice is an important crop in cropping systems. It is mainly grown in rotation with soybean or dry bean. In cerrado region of Brazil (central part of the country), upland rice is first grown after clearing the land for pasture establishment. Nitrogen is one of the most yield limiting nutrients for annual crops around the world and its efficient use is important for economic sustainability of cropping systems. Furthermore, the dynamic nature of N and its propensity for loss from soil-plant systems creates a unique and challenging environment for its efficient management (Fageria and Baligar 2005). Recovery of N in crop plants is usually less than 50% worldwide (Raun and Johnson 1999). This has led to environmental contamination and concerns regarding use of N fertilizers. The low recovery of N is associated with its loss by leaching, volatilization, denitrification and erosion of the soil. Nitrogen rate and timing are important crop management practices for improving N use efficiency and crop yields (Fageria and Baligar 2005). In addition, improving N use efficiency can reduce cost of crop production as well as environmental pollution. Synchrony of N supply with crop demand is essential in order to ensure adequate quantity of uptake and utilization and optimum yield. 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). Synchrony of nutrient supply with crop demand can improve crop yield and quality and avoiding negative environmental impacts. The objective of this study was to determine optimal timing of N fertilization on grain yield and yield components of upland rice.

Materials and methods

A greenhouse experiment was conducted at the National Rice and Bean Research Center of Embrapa, Santo Antônio de Goias, Goias, Brazil to determining optimal N fertilization timing for upland rice. The soil used in the experiment was an Oxisol and was having chemical and physical properties as pH 5.7, Ca 1.26 $cmol_c/kg$, Mg 0.64 $cmol_c/kg$, Al 0.1 $cmol_c/kg$, P 1.7 mg/kg, K 39 mg/kg, Cu 1.3 mg/kg, Zn 1.1 mg/kg, Fe 65 mg/kg, Mn 14 mg/kg, and organic matter 23 g/kg. The textural values were clay 643 g/kg, silt 100 g/kg, and sand 257 g/kg. The experiment was conducted in plastic pots with 9 kg of soil in each pot. The total N applied was 300 mg/kg and N timing treatments were: T_1 (1/2 N applied at sowing + 1/2 applied at panicle initiation), T_2 (total N applied at sowing), T_3 (1/3 N applied at sowing + 1/3 N applied at active tillering + 1/3 N applied at the panicle initiation), T_4 (1/2 N applied at initiation of tillering + 1/2 N applied panicle initiation), and T_5 (2/3 N applied at sowing + 1/3 N applied at panicle initiation). Each pot received 200 mg P and K and 5 mg Zn/kg of soil at sowing time. The N was applied as urea, P as super triple, K as potassium chloride and Zn as zinc sulfate. In addition, 10 g dolomitic lime was added four weeks before sowing and pots were subjected to wetting and drying cycles. An advance line of upland rice BRA052023 was planted. After germination four plants were maintained in each pot. completely randomized block design was used with four replications. Pots were irrigated daily to maintain soil moisture at about field capacity. Plants were harvested at physiological maturity. At the time of harvesting, panicles and shoots were harvested separately and dried to a constant weight at 70 ^{0}C. Grain harvest index was calculated by using the following formula (Fageria 2009):

$$\text{Grain harvest index (GHI)} = \frac{Grain\ yield}{Grain\ plus\ straw\ yield}$$

Data were analyzed by analysis of variance and treatment means were compared using the Tukey mean separation procedure. Regression equations were also used wherever necessary.

Results and discussion

Grain yield

Grain yield was significantly influenced by nitrogen timing treatments (Table 1). It varied from 3.87 to 12.65 g per plant with an average value of 9.73 g per plant. Maximum grain yield of 12.65 g per plant was obtained with the N timing treatment of 1/3 at sowing + 1/3 at active tillering and 1/3 at panicle initiation growth stage. The second best N timing treatment in relation to grain yield was 1/2 N applied at the initiation of tillering and remaining half at the panicle initiation growth stage. Grain yield produced at this treatment was 12.32 g per plant. The lowest grain yielding treatment was the entire N applied at sowing. The grain yield at this treatment was 3.87 g per plant. The lowest grain yield at the treatment when the entire N was applied at sowing may be associated with N losses due to volatilization and/or denitrification. There was less time for volatilization or denitrification losses when N was applied in split fractions. Fageria and Baligar (2005) reported that a substantial amount of N may be lost through volatilization and denitrification in upland soils after irrigation. The root system was also not well developed at the beginning of plant growth or seedling growth stage and plants could not absorb the entire N applied at sowing. Split application of N has been reported to increase rice yield in USA and India (Balasubramanian 2002; Walker *et al.* 2006). However, these studies were conducted for lowland or flooded rice and not for upland rice.

Shoot dry weight

Shoot dry weight also significantly influenced by N timing treatments (Table 1). Maximum shoot dry weight of 13.91 g per plant was obtained in the treatment which received 1/2 N at initiation of tillering + 1/2 at panicle initiation. The second treatment which produced maximum shoot dry weight of 12.71 g per plant was 1/3 at sowing + 1/3 at active tillering + 1/3 at panicle initiation growth stage. The minimum shoot dry weight of 4.69 g per plant was produced in the treatment which received whole N at sowing. At this treatment the shoot dry weight was 197% lower compared to highest shoot weight producing treatment, 1/2 N applied at initiation of tillering + 1/2 applied at panicle initiation. Increase in shoot weight is important because it is significantly associated with grain yield (Fageria 2007). Shoot dry weight was having a significant positive quadratic association with grain yield ($Y = -4.4195 + 2.6903X - 0.0949X^2$, $R^2 = 0.9189^{**}$). Hence, about 92% variability in grain yield was due to shoot dry weight. Fageria (2007) reported significant positive association of shoot dry weight with rice grain yield.

Panicle number

Panicle number varied from 2.75 to 7.69 per plant under different N timing treatments (Table 1). Treatment T_3 (1/3 N applied at sowing + 1/3 N applied at active tillering + 1/3 N applied at panicle initiation growth stage) produced maximum panicle followed by T_4 treatment (1/2 N applied at initiation of tillering + 1/2 N applied at panicle initiation growth stage). Treatment T_2 (total N applied at sowing) produced minimum number of panicles. Higher number of panicles in the T_3 and T_4 treatments reflected in higher grain yield in these two treatments (Table 1). Similarly, lower number of panicles in the treatment T_2 reflects in lower grain yield in this treatment. Grain yield was significantly and linearly increased with increasing panicle number ($Y = -0.7337 + 1.7256X$, $R^2 = 0.8873^{**}$). There was about 89% variability in grain yield due to panicle number. Fageria (2007) and Fageria (2009) reported highly significant relation between grain yield and panicle number in rice. Gravois and Helms (1992) reported that optimum rice yield could not be attained without optimum panicle density of uniform maturity.

Grain harvest index

The ratio of reproductive or economical yield to total dry weight is referred to as the grain harvest index (GHI). The GHI is a useful index in evaluating treatment effects on partition photoassimilates to grain within a given environment (Fageria 2009). The GHI varied from 0.45 in the T_2 treatment (whole N applied at sowing) to 0.53 in the T_5 treatment (2/3 N applied at sowing and 1/3 applied at panicle initiation) (Table 1). Fageria (2007) reported that GHI changes with cultivar and with the environmental conditions during the reproductive growth stage. The GHI is an important plant trait for improving grain yield in cereals (Fageria 2007). Furthermore, higher nitrogen use efficiency has also been observed in rice cultivars with high harvest index (Fageria 2007). The GHI values of modern crop cultivars are commonly higher than old traditional cultivars for major field crops (Ludlow and Muchow 1990). Mae (1997) reported that the grain harvest index of traditional rice cultivars is about 0.30 and 0.50 for improved, semi-dwarf cultivars. George *et al.* (2002) reported that upland rice yield can be significantly improved with developing genotypes of higher grain harvest index. The GHI is an important plant trait for improving grain yield in cereals (Fageria 2007). Furthermore, higher nitrogen use efficiency has also been observed in rice cultivars with high harvest index (Bufogle *et al.* 1997).

Conclusions

Rice is the staple food for more than 50% of the world population. In addition, nitrogen fertilizer is a major input for upland rice production in South America and its appropriate management is important in efficient crop production. Inefficient use of N may increase cost of crop production and also cause environmental pollution. Use of adequate N rate with appropriate application time is an important strategy in improving N use efficiency. Based on the results of this study it can be concluded that maximum grain yield of upland rice was obtained with the split application of N. Plant growth like shoot dry weight, and yield component like panicle number significantly and positively associated with grain yield.

Table 1. Grain yield, shoot dry weight, panicle number and grain harvest index as influenced by nitrogen timing treatments.

Nitrogen timing treatment[1]	Grain yield (g/plant)	Shoot dry weight (g/plant)	Panicle number (/plant)	Grain harvest index
T_1	9.63b	8.83b	6.31b	0.52ab
T_2	3.87c	4.69c	2.75c	0.45c
T_3	12.65a	12.71a	7.69a	0.50abc
T_4	12.32ab	13.91a	7.25ab	0.47bc
T_5	10.16ab	8.93b	6.31b	0.53a
Average	9.73	9.81	6.06	0.49
F-Test	**	**	**	**
CV(%)	12.8	12.4	10.1	5.8

**Significant at the 1% probability level. Means followed by the same letter in the same column are not significant at the 5% probability level by the Tukey test. [1]T_1 (1/2 N applied at sowing + 1/2 applied at panicle initiation), T_2 (total N applied at sowing), T_3 (1/3 N applied at sowing + 1/3 N applied at active tillering + 1/3 N applied at the panicle initiation), T_4 (1/2 N applied at initiation of tillering + 1/2 N applied panicle initiation), and T_5 (2/3 N applied at sowing + 1/3 N applied at panicle initiation).

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