Efficient and flexible management of nitrogen for rainfed lowland rice

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Received 5 June 2002; accepted in revised form 19 November 2002

Key words: Fertilizer N timing, Indigenous N supply, N-use efficiency, Risk avoidance, Soil organic matter, Suboptimal N supply

Abstract

Nitrogen (N) is the most limiting nutrient in the rainfed lowland rice soils of Laos. Indigenous N supply of these soils was low, ranging from 12 to 64 kg N/ha and was correlated with soil organic matter content. Resource-poor farmers and erratic rainfall are characteristic features of Lao rainfed lowland rice systems. Such climatic and economic factors influence farmers’ ability to apply N at the ‘recommended’ time and therefore efficient and flexible recommendations are required. Research on N management focused on the timing of N applications. Splitting the N recommendation into three equal splits at transplanting, active tillering and panicle initiation increased yields by 12% compared to a single application at transplanting. Agronomic efficiency (AE = kg increase in grain yield/kg N applied) was further increased by 9 kg/kg N if a higher proportion of the N was applied during active tillering and panicle initiation when crop N demand is high. Under conditions of suboptimal N supply, the first N application can be applied from transplanting to 30 d after transplanting without lowering grain yield or AE (for medium duration varieties transplanted 1 month after sowing). The last N application can be made between two weeks before to one week after panicle initiation without lowering yield. These findings provide the basis for an efficient (AE of 20 to 25 kg/kg N) and flexible N management strategy for Lao rainfed lowland rice under conditions of suboptimal N supply.

Introduction

Rainfed lowland rice is grown on level to slightly sloping bunded fields with non-continuous flooding of variable depth and duration (Zeigler and Puckridge 1995). This type of rice occupies about 46 million hectares or 35% of the global rice area, mostly in South and Southeast Asia (Maclean et al. 2002). Rainfed lowland rice farmers generally have fewer resources and limited access to credit (Zeigler and Puckridge 1995); therefore, risk avoidance is likely to preoccupy rainfed farmers more than irrigated farmers (Dobermann and White 1999). Large areas of rainfed lowland rice, including those in Laos, are characterized as having poor soils with a high degree of spatial and temporal variability of water availability (Zeigler and Puckridge 1995). This has direct implications for nutrient, and particularly nitrogen (N) management.

These socioeconomic and environmental constraints require that nutrient management strategies provide flexibility to adjust depending on the progress of the season (Dobermann and White 1999) and maximize fertilizer-use efficiency of suboptimal fertilizer rates. Nitrogen management is of particular concern, as it is the most limiting nutrient in Lao lowland rice systems (Linquist et al. 1998). Nitrogen is also required by rice in higher quantities, and is more susceptible to losses than other nutrients (Schnier 1995). Strategies for rainfed lowland rice N management are commonly derived from those for irrigated rice; doing so raises some concerns. Firstly, recommendations for irrigated rice lack flexibility, since water is controlled and N is applied when needed. In the rainfed environment, water is not controlled and soil water conditions oscillate between periods of being anaerobic (standing water) and...
aerobic (drained). In sandy soils, as are common in Laos, high percolation rates further reduce the time the field has standing water (Fukai et al. 1998). It may not be possible to apply N at the ‘recommended’ time, since N should be applied to standing water to avoid denitrification losses. Therefore, windows of opportunity need to be identified when N can be applied without compromising yields. Secondly, the objective of N management in irrigated rice is to optimize yields, so N is managed to avoid N deficiencies (i.e. chlorophyll meters or leaf color charts – Peng et al. 1996; Dobermann and White 1999). In the rainfed environment, due to risk and limited capital, N is applied at suboptimal rates. This implies that N deficiencies will occur at some stage during crop growth and research needs to focus on identifying when N deficiencies are least critical.

The International Rice Research Institute has been collaborating with the Lao National Rice Research Program since 1991 to develop nutrient management strategies for rainfed lowland rice. The objective of this paper is to present and summarize results from experiments which have focused on N management strategies to use N efficiently at sub-optimal N rates and to provide the necessary flexibility.

Materials and methods

All research was conducted from 1991 to 2000 during the wet season under rainfed conditions, unless otherwise stated. Experiments were conducted on-farm under the supervision of local researchers. Seedlings (25 to 35 d old) were transplanted at a hill spacing of 20 × 20 cm (25 hills/m²) using 3 to 5 seedlings per hill. Improved glutinous rice varieties (the preferred rice type in Laos) were used in all cases but the specific variety varied depending on location. All varieties were medium duration, ranging from 125 to 145 d (seed to maturity). Urea was the source of N in all experiments and was applied to standing water. Unless otherwise indicated, N was applied in three split applications with the second and third applications being applied at 30 and 50 d after transplanting (DAT), which corresponds to active tillering and panicle initiation for the medium duration varieties used in these studies. Phosphate and K were incorporated before transplanting to ensure that these nutrients were not limiting. The plot size at different sites ranged from 15 to 25 m², and all plots were separated by bunds. Grain yield estimates were made from the middle of each plot (avoiding border rows) and yields were adjusted to 14% moisture.

Results presented here represent over 90 experiments that were conducted over a 10 yr period throughout Laos. Climatic conditions varied between years and locations. The analysis of results presented here includes only those experiments where the rice did not suffer from physiological drought or prolonged flooding (water covering the rice canopy). In such cases, N management recommendations would most likely differ.

Indigenous N supply

Indigenous N supply (INS) is defined as the amount of N taken up by the crop from indigenous sources when sufficient amounts of other nutrients are supplied and other nutrient limitations are removed (Dobermann and Fairhurst 2000). INS can be estimated from ‘minus-N’ grain yields by

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\text{INS (kg/ha)} = \text{GY} \times 13
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where GY is grain yield (t/ha) in the ‘minus-N’ plots (where only N is limiting) and 13 is the amount of N (kg/ha) taken up by rice to produce 1 ton of grain (Dobermann and Fairhurst 2000). Based on data from five rainfed lowland rice experiments in Laos, 12.6 kg N/ha (standard deviation = 1.3 kg) was required to produce 1 ton of grain (data not shown).

Between 1991 and 1999, 32 experimental sites (11 from the north and 21 from the south – see Figure 1) had ‘minus-N’ plots (with P and K added) and soils (0–20 cm) that were analyzed for carbon (Tyurin 1931). Soil carbon was converted to soil organic matter (SOM) by multiplying by a factor of 1.725. INS was estimated using Equation 1 and regression analysis was used to examine the relationship between SOM and INS.

Improving N-use efficiency and management flexibility

For the purposes of this paper, agronomic N-use efficiency (AE) is used as the measure of N-use efficiency. This incremental efficiency from applied N is proportional to the cost–benefit ratio from investment in N inputs (Cassman et al. 1996b) and is calculated as