Nutrient Management in Rainfed Lowland Rice-Maize Cropping Systems of Indonesia

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Abstract. Rice-maize is an important rotation in the rainfed lowland areas of Indonesia. Low crop yields associated with poor nutrient-use efficiency are the major production constraint in these areas. Therefore, improving nutrient-use efficiency by balancing and phasing nutrients for both crops in a systemic perspective is a key concern. Toward that objective, an experiment was conducted at the ICERI experimental farm in Maros during the wet and dry seasons of 2007 with four tranches (phasings) of NPKS fertilizer in a rice-maize rotation in a randomized block design with four replications. Dividing the combination of four fertilizers (600 kg ha^{-1} urea + 200 kg ha^{-1} SP 36 + 200 ha^{-1} KCl + 100 kg ha^{-1} ZA) into two tranches, 50% for rice and 50% for maize, gave the highest yield of both rice (5.01 t ha^{-1}) and maize (8.30 t ha^{-1}). This finding suggests that for higher productivity in a rainfed lowland ecosystem fertilizer nutrients should be applied in phases with a systemic approach.

Key words: Cropping system, rice-maize, nutrient management, rainfed lowland.

Introduction

Maize development is a priority task for the Indonesian Government because it is an important feed and industrial material whose demand has been increasing (Deptan 2002). In Indonesia maize is generally cultivated in dryland areas but its production is not sufficient to meet national demand. Increasing domestic demand has spurred the cultivation of maize in irrigated lowlands and rainfed lowlands. The growth rate of maize planting area in the lowlands and rainfed lowlands has been estimated at 10-15% and 20-30% respectively (Kasryno 2002).

Maize development in the lowlands holds more promise compared to drylands. To boost productivity of rice and/or maize in the rice-maize cropping system, it needs efficient fertilizer management to improve the nutrition status of the soil. Cambirato and Frederick (1994) reported that N fertilization of maize increased the NO_3-N of soil for the succeeding wheat crop, leading an increase in dry material, N content and grain yield of wheat. However, fertilizer rates for rice-maize cropping systems are conventionally calculated separately for each commodity regardless of the fertilizer residue of the preceding crop.

Fertilizer applied to soil is not entirely taken up by the plant. Only 55-60% of the nitrogen (Patrick and Ready 1976), 20% of the phosphorus (Hangin and Tucker 1982; Goswani *et al*. 1990), 50-70% of the potassium (Tisdale and Nelson 1985) and 33% of the sulfur (Morris 1987) is absorbed. Therefore, when using inorganic fertilizer for rice-maize cropping in the lowlands, the fertilizer residue of each commodity should be considered. If not, it may result in an imbalance in the soil's nutrient levels. Accumulation of P may lead to deficiency of Zn; K accumulation may restrict the absorption of Ca; and sulfur (S) accumulation may change the soil pH.

Materials and Methods

This experiment was conducted in a rainfed lowland plot at the Maros experimental farm of ICERI in the wet and dry seasons of 2007. We used a randomized block design with four replications, and the plot size was 6 m × 4 m. The rates of NPKS fertilizer used in the different tranches are given in Table 1, the total amounting to 600 kg urea + 200 kg SP 36 + 100 kg KCl + 100 kg ZA ha^{-1}. Rice was planted in the wet season (Jan-May). The first plowing was done in a dry condition and the second harrowing in saturated conditions. The land was prepared using a tractor/hoe for levelling. The rice variety Cisantana was planted with 20 × 20 cm spacing, one seedling per hill. Fertilizers ZA and SP 36 were applied in two phases: 50% fertilizer applied 7 days after planting (DAP) and 50% 25 DAP; KCl was applied in 50% doses at 7 DAP and 40 DAP. Urea was applied three times: 7 DAP, 25 DAP and 40 DAP. Pest and disease management was done by monitoring and control if disease occurred.

The maize variety Bima-3 Bantimurung was planted immediately after rice was harvested (Jun-Sep 2007) with no tillage. Planting was done at the rate of two seeds per hole with 75 cm × 20 cm spacing. Pruning to one plant per hill was done at 6 DAP. Weeds were controlled with the herbicide Glifosfat (active ingredient) at the rate of 2 L ha^{-1}. Fertilizing was done beside the plant at 7 DAP with ZA and SP 36 applied whole, urea applied at the rate of 110 kg ha^{-1} and 50% of KCl. The remaining dose of urea and KCl was applied at the V9 phase (40 DAP.)

Data collection

Soil samples were collected before the planting of rice and maize. The sampling method was random at 0-40 cm depth over the whole plot and then composited. Plant height was measured from the base of the stem to the tip of the highest leaf at harvest time. Grain yield was measured on 3 m × 3 m size per plot and converted to 14% water content.

Results and Discussion

The soil at the research site was classified as an Entisol with silty clay texture, moderately acidic pH, low N content, moderate K level, high CEC and basin saturation (Table 2). Such soils are good enough to support maize growth although they still need additional fertilizer especially in soils with low nutrient status.

Recordings of rice plant height at harvest showed that if 75% (450 kg urea + 75 kg ZA + 150 kg SP 36 + 150 kg KCl ha^{-1}) of the total fertilizer dosage was given to rice, it gave the highest plant height, even though the result was not significantly different from the other fertilization treatments. However, allocation of 75% of the total fertilizer dosage to rice would have a predominance of urea, which accelerates vegetative growth in rice but on the other hand decreases generative growth and affects grain yield. Application of 50% (300 kg urea + 50 kg ZA +100 kg SP 36 + 100 kg KCl ha^{-1}) of the total fertilizer to rice gave the highest yield of rice grain (5.01 t ha^{-1}), while the same rate of fertilizer allocated to maize gave a yield of 8.30 t ha^{-1}. This means that 300 kg of urea ha^{-1} was enough for optimum maize grain yield. Zhao *et al*. (2006) reported that optimum N fertilizer dramatically decreased NO_3-N flow to the deeper layers of the soil. Even so, N would be available to the succeeding crop.

Allocation of 75% (450 kg urea + 75 kg ZA + 150 kg SP 36 + 150 kg KCl ha^{-1}) of the total fertilizer to rice gave a high enough yield of maize grain (6.62 t ha^{-1}). This phenomenon indicated that residual fertilizer from rice was available to the succeeding maize. Steven *et al.* (2005) reported that the N residue in the soil only accrued to the succeeding crop if the N rate had exceeded optimum. Our study indicated that apportioning 50% of the total fertilizer dosage to rice and maize in a rice-maize cropping system attained the highest total grain yield (13.30 t ha^{-1} in our study) compared to the other fertilizer allocations we studied. This finding suggests that for higher productivity in a rainfed lowland ecosystem, fertilizers should be applied in appropriate allocations taking the cropping system as a whole.

Table 1. Fertilizer dosage used for rice-maze cropping in a rainfed lowland area, Maros, Indonesia, 2007.

Treatment	Dosage[1] of NSPK (kg ha^{-1})	
	Rice	Maize
A (control)	250	350
Rice	50	50
Maize	100	100
	100	100
B	450	150
Rice 75%	75	25
Maize 25%	150	50
	150	50
C	300	300
Rice 50%	50	50
Maize 50%	100	100
	100	100
D	150	450
Rice 25%	25	75
Maize 75%	50	150
	50	150

[1.] Total fertilizer dosage for rice-maize cropping system: 600 kg urea + 100 kg ZA + 200 kg SP 36 + 100 kg KCl ha^{-1}.

Table 2. Soil analysis before rice planting in rice-maize cropping system in Maros, Indonesia, 2007.

Variable	Value	Status
Texture		
Clay (%)	22	Silty clay
Silt (%)	43	
Sand (%)	35	
pH H_2O (1:2.5)	5.90	Moderately acid
pH KCl (1:2.5)	4.88	
Organic C (%)	0.99	Low
N total (%)	0.10	Low
C/N	9.9	Low
P (Baray I (ppm)	13.70	Moderate
Kdd (me/100 g)	0.45	Moderate
Cadd (me/100 g)	18.45	High
Mgdd (me/100 g)	1.11	Moderate
Nadd (me/100 g)	0.58	Moderate
H^+	0.29	-
CEC (me/100 g)	27.82	High
Basin saturate (%)	74	Very high

Table 3. Plant height and grain yield of rice and maize under different allocations of NPKS fertilizer[1], Maros, Indonesia, 2007.

Treatment	Rice		Maize	
	Plant height (cm)	Grain yield (t ha^{-1})	Plant height (cm)	Grain yield (t ha^{-1})
A. Control	122.4ab	4.90ab	204.3a	8.11a
B. Rice (75%) Maize (25%)	120.1ab	3.91b	208.1ab	6.62b
C. Rice (50%) Maize (50%)	122.4a	5.01a	210.4ab	8.30a
D. Rice (25%) Maize (75%)	120.4ab	4.41ab	215.7b	8.41a
CC (%)	5.0	12.3	3.0	8.2

[1.]Total fertilizer used in rice-maize cropping system: 600 kg urea + 100 kg ZA + 200 kg SP 36 + 100 kg KCl ha^{-1}.

Conclusions

Allocation of the total NPKS fertilizer dosage (600 kg urea + 200 kg SP 36 + 200 KCl + 100 kg ZA ha^{-1}) in equal proportions, 50% to rice and 50% to maize in a rice-maize cropping system gave the highest yield of both rice (5.01 t ha^{-1}) and maize (8.30 t ha^{-1}). This finding suggests that fertilizer use efficiency and productivity of a rice-maize cropping system in the rainfed lowlands of Indonesia would be optimized if the fertilizer dosage was appropriately apportioned to the two crops.

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