Soil nitrogen supply and nitrogen uptake for local rice grown in unfertilized acid sulfate soil in South Kalimantan

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Most of acid sulfate soil areas in South Kalimantan are recommended for growing rice. Due to unfavourable soil conditions such as low pH and unpredictable water level, farmers grow local rice varieties. The farmers use a multiple transplanting system not only to multiply the seedling population but also to cope with the conditions. In addition, most farmers do not apply fertilizer after the last transplanting, but the yield level is not low. Nutrient (particularly nitrogen, N) availability and utilization by the rice crop are the key for this, but N balance in the local multiple transplanting system has been poorly understood. We therefore studied the balance between soil N supply from the mineralization and crop N uptake in the local transplanting system in South Kalimantan.

The experiment took place in Tambaksirang Baru (03°26’31”S, 114°35’29”E), Gambut District South Kalimantan. Two farmers’ paddocks separated by a village road were chosen for the study. The N mineralisation measurements were carried out on a monthly basis after the planting. At each sampling date, above and belowground parts of rice plants were collected for biomass and N content determination.

At the end of the growing season, we observed that the biomass, N uptake and release from the soil were 9.5 and 7.1 Mg DM ha⁻¹; 36.0 and 27.8 kg N ha⁻¹; and 13.37 and 8.32 kg N ha⁻¹ for plot 1 and 2 respectively. The higher N in the crop than that supplied by soil indicates that there are other sources of N for local rice grown in acid sulfate soil.

Key words: Nitrogen mineralisation, Siam Unus variety, multiple transplanting

Tidal swamp area in South Kalimantan is quite large and unique. According to Ismangun & Karamah (1994) the area is around 200,000 ha. As far as the area is concerned, it is important for rice growing area. The tidal swamp area is characterized by poor chemical properties and deep water level. The poor chemical properties include low soil pH and high in Fe and Al concentration. Combination of high rainfall and effect tidal movement make this area have excessive water in a certain period of the year.

Under such conditions, farmers in this area use rice varieties that are not only tolerant to the acidic environments but also taller to avoid flooding. Most farmers grow local rice varieties that have been proven to be adaptive to the conditions (Hasegawa et al., 2004b). In addition, the local rice varieties are less responsive to fertilizer application compared to improved varieties (Hasegawa et al., 2004c). This is another important reason for use of such varieties.

Despite the fact that minimum fertilisers are used, the grain yield level at farmers’ field is not necessarily low. According to the yield survey of 60 paddy fields in this area, grain yields averaged 2.6 t ha⁻¹ and 10% of the fields studied exceeded 4t ha⁻¹ (Hasegawa et al., 2004a). Nutrients (particularly nitrogen, N) availability and utilization by the rice crop are the key for the reasonably good yield in this region, but N balance in the local multiple transplanting system has been poorly understood. We therefore studied the balance between soil N supply from the mineralization and crop N uptake in the local transplanting system in South Kalimantan.

MATERIALS AND METHODS

Site

The experiment was carried out in a farmer’s paddock. The paddock is in Tambak Sirang Baru Village (GPS 03°26’31”S, 114°35’29”E). The soil was classified as gleysoils (Deckers et al. 1998). The paddock has been cultivated for rice for more than 20 years.
Planting system
The paddock was grown with a local rice variety called Siam Unus. The farmer used a multiple transplanting system in preparing the seedling. The multiple transplanting system included seedling stage in early October 2000, followed by the first transplanting in early December 2000, the second transplanting in January 2001 and finally, last transplanting (planting) in early April 2001. Details of such unique cultural practice were explained in more detail in (Hasegawa et al., 2004a).

Paddock preparation
Approximately a month prior to planting, farmer prepared the paddock. To prepare the paddock, farmer cut the weeds using a special hand hoe and let the weed to decompose. Before planting the un–decomposed weeds were dragged to the edge of the paddock. No fertilizer was applied during the growing season.

Selected soil properties
The soil samples were collected from a depth of 25 cm from 3 sites within the area of the paddock and were obtained from the first sampling period. The soil from each replicate was air–dried, ground to < 2mm and stored prior to analysis. The properties of the soil are shown in Table 1.

Experiment procedures
In this experiment N mineralisation and plant N uptake were measured throughout the growing season (14 April –28 August 2001). Nitrogen mineralisation was measured by inserting 2 PVC tubes (internal diameter of 10 cm) into 25 cm depth. The arrangement of the tubes is shown in Fig. 1.

The first tube was excavated on the same day and the other tube was kept in the field for 4 weeks with the lid on. After excavating the tubes, mineral N (NH₄⁺ + NO₃⁻) was determined. Details of the procedures were explained elsewhere (Purnomo et al., 2000). These activities were replicated 3 times for each plot. The N mineralisation measurement was conducted in every 4 weeks interval throughout the growing season.

In each soil sampling period, crop biomass (plant top + root) was also sampled. The plant samples were randomly taken from 3 hills out of 15 hills around the tube. The plant top and root were washed; oven dried 70 °C, ground and determined their N content.

Soil and plant analysis
The NH₄⁺ and NO₃⁻ concentrations were determined following extraction of approximately 40 g of fresh soil in 200 mL of 1 M KCl for 1 hour. The NH₄⁺ concentration in the extract was measured colorimetrically (Kemper and Zweers 1986). The concentration of NO₃⁻ in the extract was measured colorimetrically (Yang et al. 1998).

The N content of the whole plant (top and root) was determined by digesting the plant material using kjeldahl reagent. The N content in digest was measured by

| Table 1. Selected Soil Properties at plot 1 and plot 2 |
|---------------------------------|-----------------|-----------------|-----------------|
| **Selected soil properties**    | Plot 1          | Plot 2          | Category*       |
| Organic C (%)                  | 6.72            | 5.92            | very high      |
| Organic N (%)                  | 0.55            | 0.44            | high           |
| C/N ratio                      | 12.37           | 13.75           | medium         |
| P Bray 1 (mg P kg⁻¹)           | 0.29            | 0.96            | very low       |
| pH (H₂O)                       | 3.83            | 3.87            | very acid      |
| Exchangeable Ca [cmol(+) kg⁻¹] | 0.88            | 0.84            | very low       |
| Exchangeable Mg [cmol(+) kg⁻¹] | 0.13            | 0.19            | very low       |
| Exchangeable K [cmol(+) kg⁻¹]  | 1.43            | 0.82            | very high and high, respectively |
| Exchangeable Na [cmol(+) kg⁻¹] | 0.38            | 0.41            | medium         |
| Exchangeable Al [cmol(+) kg⁻¹] | 3.96            | 3.54            |                |
| CEC [cmol(+) kg⁻¹]             | 39.82           | 38.81           | high           |
| Base saturation (%)            | 7.1             | 5.8             | very low       |
| Al saturation (%)              | 9.9             | 9.12            | very low       |

Note: Methode used were described in: * Djämmuddlin et al. (1994); ** Yeomans and Brenner (1986); *** Brenner and Mulvaney (1982); **** John (1970); ***** McLean (1982); **** and Hidayat (1978); and *** Barnhisel & Berstch (1982), respectively.
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Calculation and data analysis
Nitrogen mineralisation for each in situ incubation period was calculated using a formula:

\[ \text{N mineralisation} = [\text{N mineral}]_{\text{final}} - [\text{N mineral}]_{\text{initial}} \]

Variations of data obtained were shown using standard error of mean.

RESULTS AND DISCUSSION
Soil properties
The selected soil properties of plots use for the experiment are shown in Table 1. Both plots have very similar properties.

Rainfall and soil temperature
The rainfall and temperature soil data throughout the growing season are presented in Fig. 2. Total rainfall throughout the growing season was 390 mm. This amount was less than the average of last 10 years (1991–2000) which was 766 mm. It was observed that the soil temperature decreased toward the growing season. The decrease was associated with the coverage the crop canopy.
Biomass production

The course of biomass production of the rice crop is shown in Fig. 3a. There was significant increase of biomass production up to panicle initiation stage. At the end of the growing season, the dry matter accumulation was 7.1–9.5 ton ha⁻¹. It is important to note that no fertiliser was applied after the last transplanting.

N content

N content of the plant tissue in the growing season is presented in Fig. 3b. The maximum N content was 0.6 and 0.8% for plot 1 and plot 2, respectively. The N content increased up to the tillering stage and the decreased toward harvest time. The N content in comparable to the modern rice variety (Dobermann & Fairhurst, 2000).

Nitrogen mineralisation

N mineralisation during the growing season is shown in Fig. 3c. It was observed that in a growing season, N derived from the mineralisation of organic N was 8 and 13 kg N ha⁻¹, for plot 1 and plot 2, respectively. This amount is much lower than found by Purnomo et al. (2000) in soil

Fig. 3. The biomass, N content and N uptake of whole plant throughout the growing season
under wheat crop in south–eastern Australia. They found that N mineralised during growing season was 140 kg N ha⁻¹. The lower N mineralised in the present study may be due low quality of organic material or reduce condition.

**N uptake**
The course of N uptake for the growing season is demonstrated in Figure 3c. The N uptake by crop increased up to the panicle initiation stage and steady after that. The highest N uptake was 36 kg N ha⁻¹. It can be seen also that after the tillering stage, N uptake was higher than N released from the soil organic N. This indicates that there may be some sources of N other than N from the soil organic N, such as the role of N fixing bacteria (Hashidoko, Y., Hasegawa, T., Purnomo, E. and Osaki, M. 2006. Rhizoplane pH and Rhizoplane microflora of local rice varieties grown on acid sulfate soil in South Kalimantan. Proceedings of the International Symposium on Land management and Biodiversity in Southeast Asia. September 17–20, 2002 Bali, Indonesia).

**CONCLUSION**
From the study area we found that without fertiliser after last transplanting there a huge accumulation crop biomass. Surprisingly, N uptake of the local rice exceeded the N originated from the release of the organic N. It may be N fixing bacteria contributed to the remaining N in the crop.

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