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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 transplating

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 gleysols (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 through out 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 (NH_4^+ + NO_3^-) was determined. Details of the procedures were explained else where (Purnomo *et al.*, 2000). These activities were replicated 3 times for each plot. The N mineralisation measurement was conducted in every 4 weeks interval through out 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 NH_4^+ and NO_3^- concentrations were determined following extraction of approximately 40 g of fresh soil in 200 mL of 1 M KCl for 1 hour. The NH_4^+ concentration in the extract was measured colorimetrically (Kempers and Zweers 1986). The concentration of NO_3^- 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[a)]
Organic C (%)[b]	6.72	5.92	very high
Organic N (%)[c]	0.55	0.44	high
C/N ratio	12.37	13.75	medium
P Bray 1 (mg P kg^{-1})[d]	0.29	0.96	very low
pH (H_2O)[e]	3.83	3.87	very acid
Exchangeable Ca [cmol(+) kg^{-1}][f]	0.88	0.84	very low
Exchangeable Mg [cmol(+) kg^{-1}][f]	0.13	0.19	very low
Exchangeable K [cmol(+) kg^{-1}][f]	1.43	0.82	very high and high, respectively
Exchangeable Na [cmol(+) kg^{-1}][f]	0.38	0.41	medium
Exchangeable Al [cmol(+) kg^{-1}][g]	3.96	3.54	
CEC [cmol(+) kg^{-1}][h]	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: [a)] Djaenuddin *et al.* (1994); [b)] Yeomans and Bremner (1986); [c)] Bremner and Mulvaney (1982); [d)] John (1970); [e)] McLean (1982); [f)] and [h)] Hidayat (1978); and [g)] Barnhisel & Berstch (1982), respectively.

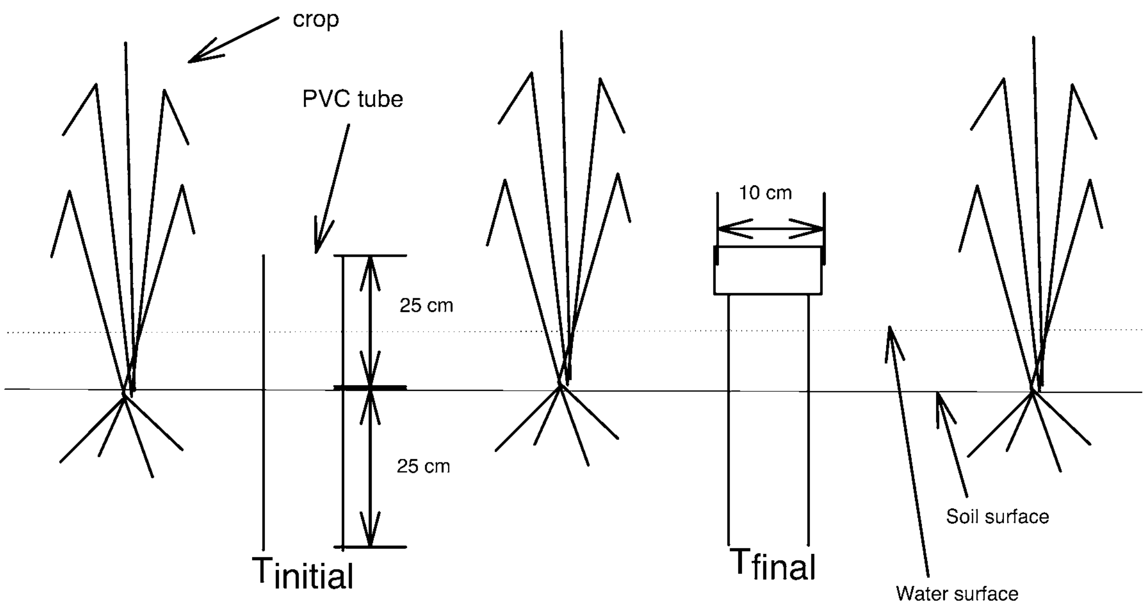

Fig. 1. The PVC arrangement in the field

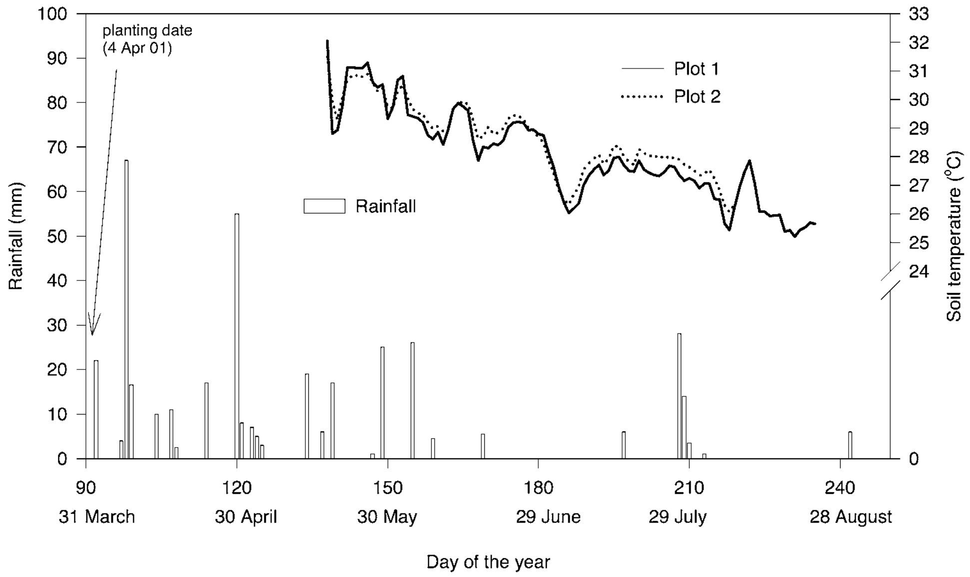

Fig. 2. The rainfall distribution and soil temperature during the growing season.

distillation.

Calculation and data analysis

Nitrogen mineralisation for each in situ incubation period was calculated using a formula:

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 through out 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 that found by Purnomo *et al.* (2000) in soil

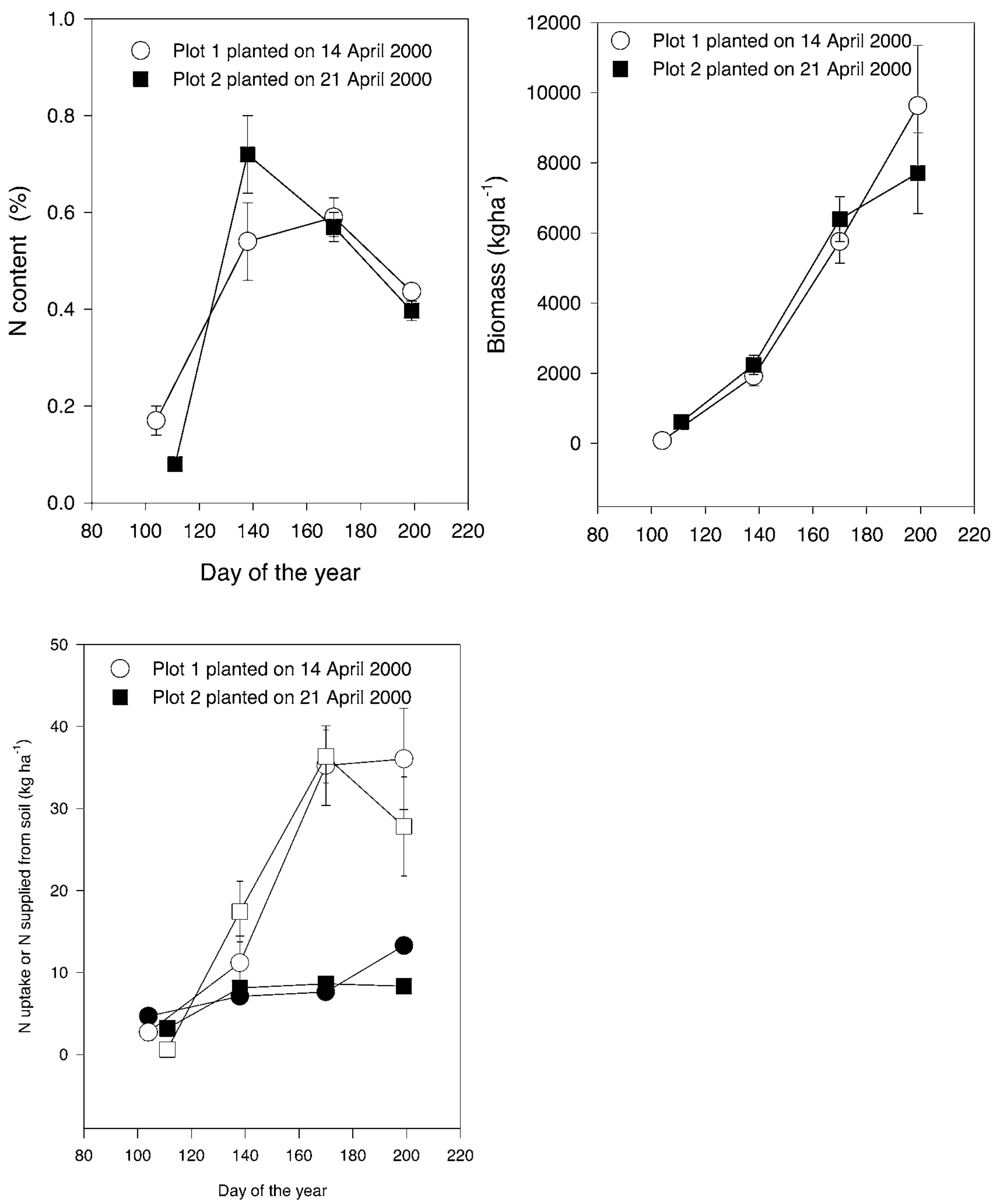

Fig. 3. The biomass, N content and N uptake of whole plant through out the growing season

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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