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Characterization of Nitrogen Uptake Pattern in Malaysian Rice MR219 at Different Growth Stages Using ^{15}N Isotope

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Abstract: Nitrogen (N) use efficiency is usually less than 50%, and it remains a major problem in rice cultivation. Controlled release fertilizer (CRF) technology is one of the well-known efforts to overcome this problem. The efficiency of CRF, however, is very much dependent on the timing of nutrient release. This study was conducted to determine the precise time of N uptake by rice as a guideline to develop efficient CRF. Fertilizer N uptake by rice at different growth stages was investigated by using ^{15}N isotopic technique. Rice was planted in pots, with ^{15}N urea as N source at the rate of 120 kg/hm^2. Potassium and phosphorus were applied at the same rate of 50 kg/hm^2. Standard agronomic practices were employed throughout the growing periods. Rice plants were harvested every two weeks until maturation at the 14th week and analyzed for total N and ^{15}N content. Nitrogen derived from fertilizer was calculated. Total N uptake in plants consistently increased until the 11th week. After that, it started to plateau and finally declined. Moreover, N utilization by rice plants peaked at 50%, which occurred during the 11th week after transplanting. N derived from fertilizer in rice plants were in the range of 18.7% to 40.0% in all plant tissues. The remaining N was derived from soil. Based on this study, N release from CRF should complete by the 11th week after planting to ensure the maximum fertilizer N uptake by rice plants. Efficient CRF should contribute to higher N derived from fertilizer which also resulted in a higher total N uptake by rice plants, increasing the potential of rice to produce higher yield while at the same time of reducing loss.

Key words: nitrogen use efficiency; rice; controlled release fertilizer; ^{15}N isotope

Nitrogen (N) use efficiency (NUE) problem has been widely discussed and studied over the years. In most agricultural crop, the efficiency is low. Use efficiency of fertilizer N in rice is often less than 50% (Katyal et al, 1985; Singh et al, 2001). Inefficient NUE can cause various adverse effects, such as serious environmental problems to the aquatic and terrestrial ecosystem, as well as the atmosphere (Dalton and Brand-Hardy, 2003). Excessive N in the environment can cause respiratory problems, such as 'bluebaby syndrome' and cancer from nitrate contamination in drinking water (Galloway and Cowling, 2002).

Fertilizer technology can be a solution for the low N efficiency problem. Controlled release fertilizer (CRF) has the ability to release its nutrient content gradually to coincide with the plant requirement (Hanafi et al, 2000). Plants can remove N in optimum amount by using CRF. CRF will supply the plants with N at the right time and at the right amount. N requirement varies during plant development. Controlled release of N will supply the N accordingly, based on plant development stages (Sharma, 1979).

The time of nutrient release from fertilizer is a crucial element to determine the effectiveness of CRF. Rapid release may cause N loss, while extremely slow release can cause N insufficiency for plant uptake. Thus, predicting N requirement by plant provides important information in designing the release pattern of the CRF.

Isotopic study by using ^{15}N can be used to determine N utilization from fertilizer by plant. Plant can obtain N from various sources, including soil, microbial fixation, and most importantly fertilizer. Fertilizer is applied as ^{15}N isotope to trace the amount of N derived from the fertilizer (NDFF). This information is very essential in developing fertilizer to meet the actual requirement of plant. The advantage of this technique is that the element is traceable. Isotopic ^{15}N is the most common stable isotope used in agriculture-related studies (IAEA, 2001).

MR219 is one of the most common rice varieties commercially cultivated in Malaysia. Its coverage reached a

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record high of 70.1% in 2002, and the latest recorded coverage was 30%–40% in 2012. Until now, this variety has remained as one of the main varieties applied in Malaysian granary areas. There are several attributes of this particular variety that have made it popular among Malaysian farmers, including short maturation period, long grade grains, low amylose content, high resistance to leaf blight and brown planthopper.

The experiment was conducted to determine the timing of N uptake and NUE by rice during the growing stages.

MATERIALS AND METHODS

Experimental setup and rice establishment

A pot experiment was conducted in a glasshouse. Commonly grown rice variety MR219 was used and the plants were grown in Selangor soil series (Isohyperthermic, Aeric Tropic Fluvaquent) collected from Sungai Besar, Selangor, Malaysia (3°42′20″ N, 100°58′08″ E).

Physico-chemical analyses of the soil were conducted. Mechanical analysis of soil was done by pipette method and textural class (clay, 64.0%; silt, 34.5%; sand, 1.3%) was determined using the United State Department of Agriculture soil textural triangle. Soil pH (6.0) was analyzed using Mettler Toledo pH meter in a 1:2.5 ratio of soil to water. Cations exchange capacity (20.2 cmol/kg) was determined using leaching method (Chapman, 1965). Total N (0.15%) was determined using Kjeldahl method with salicylic acid (Bremner and Mulvaney, 1982). Available P (8.54 mg/kg) was determined using Bray No. 2 method (Bray and Kurtz, 1945). Available Cu, Fe, Mn and Zn (0.27, 23.72, 2.70 and 0.30 mg/kg, respectively) were determined using Mehlich No. 1 method (Mehlich, 1953).

Every pot was filled with 10 kg of soil and flooded with water. Water level was maintained at 1–2 cm above the soil surface during the early growth stage and 5–7 cm at the later growth stage. Rice seeds were pre-germinated and grown for 14 d. Rice plants were transplanted into the pots filled with flooded soil at the 15th day. Every pot was planted with four rice plants and each plant was planted separately from one another in the pot.

Fertilizer application and agronomic practice

Recommended rates of 120 kg/hm^2 N, 50 kg/hm^2 P_2O_5, and 50 kg/hm^2 K_2O were applied. N in the form of ^{15}N (urea fertilizer) was applied in three splits on the first day after transplanting (DAT) or basal application, 20 DAT and 35 DAT. Urea labelled with ^{15}N used was ISOTEC™ Urea $^{15}N_2$, 10% atom excess (a.e). Phosphorus (P) in the form of triple superphosphate and potassium (K) in the form of muriate of potash fertilizer were applied as basal fertilizer. Standard agronomic practices were carried out to control insects, pests, diseases and weeds.

Plant analysis and ^{15}N measurement

Whole rice plants were harvested every two weeks after transplanting, with the final harvest done at 14th week. The harvested plants were dried at 60 °C for 24 h before they were separated into straw, roots and grains.

Total N content in plant tissues was determined using the Kjeldahl method (Bremner and Mulvaney, 1982) and total N uptake was calculated by multiplying total N with dry matter weight. The plant tissues were analyzed for ^{15}N content using an emission spectrometer (IAEA, 2001). Those analyses were conducted at Malaysian Nuclear Agency. The N utilization from the fertilizer was calculated by dividing the percentage of ^{15}N atom excess in the plant with percentage of ^{15}N atom excess in the fertilizer (IAEA, 2001). Both NDFF and N derived from soil (NDFS) in plants were calculated to determine the percentage of N from fertilizer and soil (IAEA, 2001).

NUE (%) = N from ^{15}N fertilizer / Amount of fertilizer applied × 100

Fertilizer N utilization (%) or NUE is calculated by NDFF in plant tissues with the total amount of fertilizer applied (IAEA, 2001). By using this calculation, the percentage of N from the fertilizer that was actually taken up by the plant in relation to the total amount of fertilizer applied can be estimated.

RESULTS

Nitrogen uptake by plant

The total N uptake in plant consistently increased from the first harvest in the 2nd week and reached the maximum in the 11th week (Fig. 1). After the 11th week, total N uptake in plant started to become plateau and eventually decreased.

The N uptake in rice during the second week was 6.6 g/pot. Then, it started to increase by week and reached its peak during the 10th to 12th weeks at 127.9 g/pot. Towards the end of growing period, total N in rice decreased to 112.3 g/pot during the 12th week and 128.87 g/pot during the 14th week.

Nitrogen use efficiency (NUE)

By implementing standard practice of rice cultivation in which urea was used as the source of N, NUE was only 50.0% (Fig. 2). The highest NUE was achieved towards the end of growing

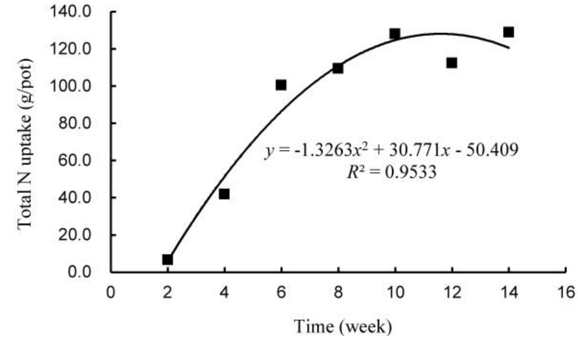

Fig. 1. Total nitrogen (N) uptake by rice plant at different weeks after transplanting.