Effects of controlled-release coated urea (CRCU) on soil microbial biomass N in paddy fields examined by the $^{15}$N tracer technique

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Abstract

Experiments were conducted in paddy fields at Shiga and Chiba Prefectures to study the effects of controlled-release coated urea (N-LP100) on soil microbial biomass and N uptake of rice plants by the $^{15}$N-tracer technique, during one cropping season. Three field fertilizer treatments (Zero N: 0 kg N ha$^{-1}$, $^{15}$N-LP100: 64 kg N ha$^{-1}$ and $^{15}$NH$_4$Cl: 100 kg N ha$^{-1}$) were set-up in the Shiga field experiment. After transplanting in the paddy fields at Shiga and Kashiwa (Chiba), a number of rice hills with standard growth were selected randomly and enclosed by polyacryl-plastic frames designated as microplots. $^{15}$N-LP100 (64 kg N ha$^{-1}$) was applied in the Shiga and Kashiwa microplot experiments and the Shiga field experiment as deep-side placement (5 cm away from rice hill and 5 cm soil depth). Total N uptake of rice plants was analyzed in the course of plant growth. In addition, soils from the field fertilizer treatment plots and microplots (divided into 11 blocks) were taken and analyzed for microbial biomass N ($B_N$) and biomass $^{15}$N ($B_{15N}$). The results indicated that; (1) Plant N uptake from basal-applied fertilizers at the end of the study in the Shiga field experiment was 71.9 and 26.0% for $^{15}$N-LP100 and $^{15}$NH$_4$Cl, respectively. In the Kashiwa microplot experiment, plant N uptake from applied $^{15}$N-LP100 was 51.2% at 67 days after transplanting (DAT) (2) Throughout the cropping season, $B_N$ was the highest, intermediate and the lowest for $^{15}$NH$_4$Cl, $^{15}$N-LP100 and Zero N field experimental plots in the Shiga experiment, respectively. (3) In the micro-plot experiments, $B_N$ and $B_{15N}$ were generally higher in the soil block with deep-side application of $^{15}$N-LP100 compared with the other soil blocks. The deep-side placement of $^{15}$N-LP100 ensured a high efficiency of utilization of its N by rice plants. The method of $^{15}$N-LP100-placement also affected the spatial heterogeneity of microbial biomass N in the microplots.

Introduction

Controlled-release coated urea (CRCU) is a urea fertilizer coated with a special resin for the regulated or controlled release of N (Shoji and Gadenza, 1992). CRCU has many advantages over conventional fertilizers, including reduction in labour with a single basal application and higher N uptake efficiency by crops (Shoji et al., 1991; Shoji and Gadenza, 1992). CRCU is also environmentally friendly in terms of reducing fertilizer N losses by leaching and de-nitrification (Ueno and Yamamuro, 1996). Most of the studies on CRCU in paddy fields so far dealt with the efficiency of N uptake and utilization and yield of rice (Kamekawa et al., 1990; Nakashima et al., 1990; Nishiyama and Yoshiba, 1997). These studies led to the recommendation that the total amount of N to be applied as CRCU for rice could be reduced by 10–30% of the normal amount necessary for the conventional method with ammonium fertilizers.

Soil microbial biomass (SMB) forms about 1–5% of soil organic matter. Despite its small fraction, SMB exhibits a rapid turnover and can be considered as a driving force behind major nutrient cycles in agricultural ecosystems. In governing nutrient supply, SMB plays dual roles as biocatalyst of the numerous soil-
based reactions and represents a rapidly turned-over pool of nutrients such as N and P in soil (Jenkinson and Ladd, 1981; Yoshikawa and Inubushi, 1995). There is a strong link between SMB and soil fertility in paddy soils (Watanabe and Inubushi, 1986; Inubushi et al., 1997). Even in an unfertilized crop, the SMB pool can supply a substantial part of the N uptake by crops (Lynch, 1983). The soil microbial biomass is influenced by the application of both organic and inorganic fertilizers. However, there is little information on the effects of any kind of CRCU on the dynamics of soil microbial biomass in paddy fields (Acquaye et al., 2000).

In this paper, we examine the effects of 15N-LP100 on plant N uptake and soil microbial biomass N. In microplot experiments, we investigated the influence of the deep-side placement of 15N-LP100 on the spatial distribution of microbial biomass N, by using the 15N-tracer technique in two paddy fields during one cropping season.

Materials and methods

Site and soil description

The studies were field and microplot experiments conducted at the paddy fields belonging to the Shiga Prefectural Agric. Expt. Stn. (Aizuchi Town, Shiga Prefecture) and a microplot experiment at Chiba University (Kashiwa City, Chiba Prefecture). Both locations are in Japan. Hereafter, the studies conducted at Shiga will be referred to as Shiga field or microplot experiment and that conducted at Kashiwa as Kashiwa microplot experiment, respectively. The soils at the Kashiwa and Shiga paddy fields were a Wet Andosol (pH: 6.5, N\textsubscript{t}: 0.39%; C\textsubscript{t}: 7.1%, biomass N: 20.22 mgN kg\textsuperscript{-1}, NH\textsubscript{4}\textsuperscript{+}-N: 5.85 mgN kg\textsuperscript{-1}) and a Medium Textured Gray Lowland paddy soil (pH: 6.36, N\textsubscript{t}: 0.25%; C\textsubscript{t}: 3.07%, biomass N: 35.25 mgN kg\textsuperscript{-1}, NH\textsubscript{4}\textsuperscript{+}-N: 10.66 mgN kg\textsuperscript{-1}), respectively.

Experimental treatments and layout

Shiga field study

Name of experimental plots, time, method, and rate of application of different fertilizers are indicated in Table 1. In the Shiga field experiment, three (15N-LP100, 15NH\textsubscript{4}Cl and Zero N) field fertilizer treatment plots were set up and planted with rice variety Kinuhi-kari on 5th May 1996. The plots were duplicated and measured 5 m × 5 m each with a 1 m × 1 m subplot demarcated in the middle for plant and soil sampling. A total amount of 8 g N m\textsuperscript{-2} (80 kg N ha\textsuperscript{-1}) was applied on the 15N-LP100 plot as basal fertilizer with 15N-LP100 (80%) plus 14NH\textsubscript{4}Cl (20%) as deep-side placement (5 cm away from rice hill and 5 cm soil depth). The 15N-LP100 (3.23 atom%) fertilizer was applied at the rate of 64 kg N ha\textsuperscript{-1}. The 15N-LP100 is a linear type CRCU with a release duration (i.e. number of days required to release 80% of its T-N in water at 25°C) of 100 days. The N is released from N-LP100 at rates and concentrations that match the specific needs of the rice plant for maximum N uptake efficiency. For the conventional 15NH\textsubscript{4}Cl fertilizer plot, a total N of 100 kg N ha\textsuperscript{-1} was applied to the whole plow layer with 15NH\textsubscript{4}Cl as basal fertilizer (30 kg N ha\textsuperscript{-1}), at tillering (30 kg N ha\textsuperscript{-1}) and at panicle initiation (40 kg N ha\textsuperscript{-1}) stages.

Shiga and Kashiwa microplot studies

The microplot experiments were specifically set up to study the spatial distribution of SMB as affected by the application of 15N LP100 since this could not be done without restricting the movement of the fertilizer. Immediately after transplanting in the Shiga and Kashiwa (Acquaye et al., 2000) paddy fields, a number of rice hills with standard growth were selected randomly and enclosed by polyacryl-plastic frames (30 × 15 × 25 cm L × B × H), designated as microplots. The frames were fixed at the planting space and pushed into the plough layer soil to a depth of about 15 cm with the rice hill in the central position. The soil in the frames was scooped out and replaced with fresh soil that had been taken from the field before basal application of fertilizers. In the Shiga experiment, each of 10 microplots set up was fertilized with a mixture of 15N-LP100 (80%) and 14NH\textsubscript{4}Cl (20%) at the same rate (80 kg N ha\textsuperscript{-1}) and method (deep-side placement) as in the field study. In the Kashiwa microplot experiment, 8 micro-plots were established. Four micro-plots were amended with 15N-LP100 (3.23 atom%), while the other 4 microplots were amended with non-labeled 14N-LP100 each, all at the same application rate (64 kg N ha\textsuperscript{-1}) and method (deep-side placement) as in the Shiga experiments.

Soil and plant sampling

Soil and plant sampling for the Shiga field experiments was carried out at 31, 59, 89 and 117 days after transplanting (DAT). On each plot, soil samples