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Short communication

Effects of single basal application of coated compound fertilizer on yield and nitrogen use efficiency in double-cropped rice

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ABSTRACT

Fertilizer plays an important role in increasing rice yield. More than half of all fertilizer applied to the field is not taken up, resulting in environmental damage and substantial economic losses. To address these concerns, a low-cost, coated compound fertilizer named "Xiang Nong Da" (XND), requiring only a single basal application, was studied. A two-year field experiment was conducted to test the effects of XND application on rice yield and nitrogen fertilizer use efficiency. An ordinary uncoated compound fertilizer (UNCF), with 20% more nutrients and split application was selected as the control. The yield of XND-treated rice was only 3.1% lower than that of the control, an insignificant difference. There were no significant differences between N use efficiency indices of the two fertilizer treatments except for N partial factor productivity (PFP_N). PFP_N of XND treatment was 19.7%–23.2% higher than the control, a significant difference. This result indicates that a 20% decrease in N application rate is possible with XND without yield reduction and with savings in both labor and time.

1. Introduction

Rice is the main staple food for >60% of China's population [1]. Fertilizer is a determining factor for rice growth and plays a vital role in maintaining rice yield. Increased fertilizer application has contributed significantly to improved rice yield [2–4]. Although fertilization drives productivity, nitrogen use efficiency in rice production is very low, with nitrogen use efficiency in China averaging only 27.5% [5]. High external N input and ineffective fertilization practices have led to low nitrogen use efficiency [2,3,6,7]. Leaching, runoff, and volatilization are the major N loss pathways. Besides the low nitrogen use efficiency, excessive fertilizer in fields harms the environment by increasing the greenhouse effect, soil degradation, and groundwater pollution [8]. In view of the present situation, many N conservation application practices such as balanced N fertilization, site-specific N management, integrated N management, nitrification inhibitor use, and controlled-release fertilizers (CRF), have

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been developed to improve nitrogen use efficiency [7,9,10]. Recently, the use of CRF has become common to lessen fertilizer consumption, increase nitrogen use efficiency, and minimize environmental pollution [9,11,12]. CRF is a type of fertilizer that controls the rate of nutrient supply. It is a polymer-coated fertilizer, generally a compound fertilizer or urea coated with polymer [13]. Many studies have found that CRF applications significantly increase nitrogen use efficiency and crop yield [14,15]. They are also more environmentally friendly fertilizers, because the N losses through leaching and denitrification are reduced [16,17,22,23]. Conventional fertilization requires frequent applications, whereas a CRF needs only a single application and is thus more labor and time saving than conventional fertilization.

Thus, study of controlled-release fertilizer techniques is important for increasing rice yield and fertilizer efficiency. The present study investigated a low-cost, coated compound controlled-release fertilizer, "Xiang Nong Da" (XND), comparing yield and N use efficiency of test rice cultivars treated with XND or a conventional compound fertilizer with two applications, XND supplied 20% fewer nutrients in the test. The study's objectives were to investigate the effects of XND treatment on rice yield and N use efficiency.

2. Materials and methods

2.1. Site description

Field experiments were conducted during the early season (late March to July) and the late season (mid-June to late October) in 2014 and 2015 in the same field located in Liuyang county, Hunan province, China (28°09′N, 113°37′E, 43 m.a.s.l.). In 2014 before the experiments, experimental site soil samples were collected from the upper 20 cm. The soil was clayey with pH 6.25, 23.49 g organic C kg^{-1}, 1.24 total N kg^{-1}, 18.24 mg kg^{-1} available P, and 112.71 mg kg^{-1} available K.

2.2. Genetic material

An early-season rural conventional rice variety "Zhongjiazao 17" was used for early-season experiments. A late-season hybrid rice variety "Shengtaiyou 9712" (Shengtaiyou A × 9712) was used for late-season experiments. These are major cultivars currently widely used in China's Yangtze River valley.

2.3. Experimental design

The experimental design was a completely randomized block with 3 replicates. Each plot had an area of 4 m × 5 m. Three fertilizer treatments were applied:

T1: a control with no N application.

T2: an ordinary compound fertilizer, N–P_2O_5–K_2O (20–5–10), produced by Hunan Hua Lu Company, at an N rate of 135 kg ha^{-1}.

T3: XND, a controlled-release fertilizer, N–P_2O_5–K_2O (20–5–10), a low-cost, self-developed polymer-coated compound fertilizer [17], produced by Hunan agricultural university, at an N rate of 108 kg ha^{-1}.

XND (T3) was used as basal fertilizer once before planting rice. The ordinary fertilizer (T2) was applied as a split application at two rice developmental stages: one (50%) at preplant and other (50%) at the tillering stage. P and K fertilizers in the T1 treatment were applied as basal dressings at the rate of 34 (P_2O_5) and 68 (K_2O) kg ha^{-1}, and were applied in T2 and T3 at the same rate.

The nursery field was prepared one week before sowing. The compound fertilizer (nutrient content > 35%) was applied to the nursery field at a rate of 450 kg ha^{-1} before plowing. Germinated seeds were sown in nursery beds at a rate of 30 g m^{-2} on May 23 for early season and June 27 for late season in both years. They were transplanted to a spacing of 20.0 cm × 16.5 cm, with three seedlings per hill. Seedling age at transplanting was 30 days in early season and 24 days in late season. The water regime management was in the sequence of shallow irrigations (2–3 cm), midseason drainage (10–15 days), and shallow irrigation. Pests and diseases were controlled using chemicals. Weeds were controlled using herbicides and hand pulling.

2.4. Measurement and sampling

2.4.1. Dry matter, yield, and yield components

Six hills were diagonally sampled from each subplot at full heading stage (when about 80% of the panicles had emerged from the flag leaf sheath). Samples were separated into leaves, stems, and panicles. Each part was oven-dried in an oven at 75 °C to constant weight.

At physiological maturity, in the middle of each subplot, ten hills of plants were diagonally sampled. Panicles were counted to calculate panicles m^{-2}. Plant samples were separated into panicles and straw (including rachis). Panicles were hand-threshed. Unfilled spikelets were then separated from filled spikelets by submersion in water. Three 30 g subsamples of filled grain and all unfilled spikelets were manually counted. Straw and filled and unfilled spikelets were oven-dried at 75 °C to constant weight. Spikelets per panicle, spikelet filling percentage, and harvest index were then calculated. Grain yield was obtained from a 5 m^2 area in each plot and adjusted to the standard moisture content of 0.14 kg H_2O kg^{-1}.

2.4.2. Leaf area index [LAI] and N content

A leaf area meter (LI-3000, LI-COR, Lincoln, NE, USA) was used to measure the green leaf area at full heading stage and LAI was calculated leaf area/unit ground area.

N concentrations in stem, filled and unfilled, were measured with a Skalar SAN Plus segmented flow analyzer (Skalar Inc., Breda, The Netherlands). N uptake was calculated by biomass multiply N content.

Nitrogen fertilizer use efficiency indices were calculated as follows:

$$\text{Applied N partial factor productivity } (PFP_N) = (GY_{+N})/FN$$

$$\text{Applied N agronomic efficiency}(AE_N) = (GY_{+N} - GY_{-N})/FN$$

$$\text{Applied N crop recovery efficiency}(RE_N)(\%) = (TN_{+N} - TN_{-N})/FN \times 100$$

$$\text{Applied N physiological efficiency}(PE_N) = (GY_{+N} - GY_{-N})/(TN_{+N} - TN_{-N})$$

where TN_{+N} = N total accumulation of aboveground plants in the plot that received N fertilizer; TN_{-N} = total N