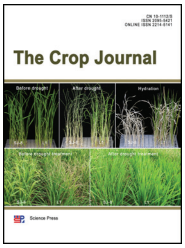
THE CROP JOURNAL XX (2018) XXX–XXX

Crop Science Society of China

Available online at www.sciencedirect.com

ScienceDirect



Improving nitrogen management for zero-tillage rice in China

Min Huang*, Xuefeng Zhou, Yingbin Zou

Southern Regional Collaborative Innovation Center for Grain and Oil Crops (CICGO), Hunan Agricultural University, Changsha 410128, Hunan, China

ARTICLE INFO

Article history:
Received 5 January 2018
Received in revised form 7 March 2018
Accepted 25 March 2018
Available online xxxx

Keywords:
Grain yield
N management
N-use efficiency
Rice
Zero-tillage

ABSTRACT

Zero-tillage has become increasingly attractive in rice production in China. This study was conducted to determine the feasibility of two possible improved N management practices with fewer N applications in zero-tillage rice: (1) two split applications of urea at 75 kg N ha^{-1} at mid-tillering and 45 kg N ha^{-1} at panicle initiation ($U_{120\text{–}2}$), and (2) a single application of cross-linked polyacrylamide-coated urea (a slow-release fertilizer) at mid-tillering at a rate of 150 kg N ha^{-1} ($PCU_{150\text{–}1}$). Three field experiments were conducted to compare grain yield and N-use efficiency among several N treatments: a zero-N control (CK), $U_{120\text{–}2}$, $PCU_{150\text{–}1}$, a single application of urea at mid-tillering at a rate of 150 kg N ha^{-1} ($U_{150\text{–}1}$), and a commonly recommended N management practice for conventional tillage rice (three split applications of urea with 75 kg N ha^{-1} as basal, 30 kg N ha^{-1} at mid-tillering, and 45 kg N ha^{-1} at panicle initiation) ($U_{150\text{–}3}$). Treatments with N application ($U_{120\text{–}2}$, $PCU_{150\text{–}1}$, $U_{150\text{–}1}$, and $U_{150\text{–}3}$) produced 1.08–3.16 t ha^{-1} higher grain yields than CK. Grain yields under both $U_{120\text{–}2}$ and $PCU_{150\text{–}1}$ were comparable to that in $U_{150\text{–}3}$. Recovery efficiency of N (RE_N), agronomic N-use efficiency (AE_N) and partial factor productivity of applied N (PFP_N) were increased under $U_{120\text{–}2}$ and were similar under $PCU_{150\text{–}1}$ to those under $U_{150\text{–}3}$. $U_{150\text{–}1}$ showed lower grain yield, RE_N, AE_N, and PFP_N than $U_{150\text{–}3}$. These results suggest that $U_{150\text{–}3}$ can be replaced with $U_{120\text{–}2}$ to achieve both an increase in N-use efficiency and a reduction in number of N applications and or by $PCU_{150\text{–}1}$ to achieve a maximum reduction in number of N applications in zero-tillage rice production in China.

1. Introduction

Rice is the staple food crop for about 65% of the population in China [1]. Although rice production in China has shown remarkable growth in the past five decades, several key problems in the Chinese rice production system prevent a sustainable increase in rice production [2]. Overuse of fertilizers, especially N fertilizer, has been one of the major problems confronting rice production in China [2,3]. The average rate of N application for rice production in China is

---

* *Corresponding author.*
E-mail address: mhuang@hunau.edu.cn. (M. Huang).

Peer review under responsibility of Crop Science Society of China and Institute of Crop Science, CAAS.

https://doi.org/10.1016/j.cj.2018.03.002

Please cite this article as: M. Huang, et al., Improving nitrogen management for zero-tillage rice in China, The Crop Journal (2018), https://doi.org/10.1016/j.cj.2018.03.002

180 kg ha^{-1}, about 75% higher than the world average [4]. Because of the high rate of N application, only 20%–30% of N is taken up by the rice plant and a large proportion of N is lost to the environment [5]. This results not only in waste of the applied N but also in many environmental problems, such as soil acidification, increased greenhouse gas emissions, and surface water eutrophication [3,6].

A sustainable increase in rice production in China has been constrained by changes in socioeconomic and physical environments, such as decreased labor availability and degraded soil [2,3]. Rice production technologies must be developed that will be labor saving and environmentally friendly and will maintain rice yield potential [7]. Conventional tillage (by moldboard plowing and rotavating) is the most widely used method for land preparation in Chinese rice production [8]. However, this practice not only requires a large amount of energy and labor [9] but also accelerates mineralization of organic matter, reduces soil fertility, increases water consumption, and damages the chemical and physical properties of the soil [10]. In recent years, zero-tillage has been become increasingly attractive in Chinese rice production [7], owing to its benefits including saving fuel, equipment, and labor as well as conserving soil [11].

As compared with conventional tillage, zero-tillage can cause accumulation of rice roots and soil N in the surface soil layer [12,13]. Thus, zero-tillage rice has more roots distributed in the soil layer with higher N content, indicating that less N fertilizer may be required in zero-tillage rice. However, Norman et al. [14] reported that zero-tillage rice took a long time to take up basal N, resulting in an increase in N loss and a consequent increase in N fertilizer requirement. Huang et al. [15] also observed that N uptake was delayed in zero-tillage rice. They further found that inhibition of root growth caused by accumulation of inhibitory pseudomonads in the rhizosphere was responsible for the poor N uptake in zero-tillage rice at early growth stages [16]. These reports suggest that the basal N rate may need to be decreased to reduce N loss in zero-tillage rice. But in fact, rice farmers in China generally follow the same N management for zero-tillage rice as for conventional tillage rice [7]. Even worse, owing to shortage of labor and increased labor costs, many rice farmers apply fertilizers only once, before crop establishment, to avoid in-season fertilizer application [2]. For these reasons, reducing the number of N applications should be a primary goal in improving rice N management to meet the changes in the socioeconomic environment. In this regard, it has been suggested [17] that the supply of N by a single application of slow-release fertilizer is likely to satisfy plant requirements.

Based on the above considerations and a commonly recommended N management practice for conventional-tillage rice (three split applications of urea at 75 kg N ha^{-1} as basal, 30 kg N ha^{-1} at mid-tillering, and 45 kg N ha^{-1} at panicle initiation) (U_{150-3}), we designed two possible improved N management practices for zero-tillage rice in China: (1) two split applications of urea at 75 kg N ha^{-1} at mid-tillering and 45 kg N ha^{-1} at panicle initiation (U_{120-2}), and (2) a single application of cross-linked polyacrylamide-coated urea (a slow-release fertilizer) at mid-tillering at 150 kg N ha^{-1} (PCU_{150-1}). The objective of this study was to test the feasibility of these two N management practices.

2. Materials and methods

Three field experiments were conducted. The details of these experiments were as follows:

2.1. Field experiment I

This experiment was conducted in Nanxian (29°21′N, 112°25′E, 30 m a.s.l.), Hunan province in a single rice-growing season in 2011. A rice–oilseed rape rotation with conventional tillage was followed in the field before the experiment was conducted. The soil of the experimental field was a purple calcareous clayey soil with the following properties in the upper 20 cm layer: pH 7.73, organic matter 28.8 g kg^{-1}, total N 1.92 g kg^{-1}, available P 29.1 mg kg^{-1}, and available K 81.2 mg kg^{-1}. The hybrid rice cultivar Liangyoupeijiu was grown under three N treatments (Table 1). The N treatments were arranged in a completely randomized block design with three replications and plot size of 20 m^2. Rice plants were established by zero-tillage transplanting. Pre-germinated seeds were sown in a seedbed. Twenty-five-day-old seedlings were transplanted at a hill spacing of 20 cm × 20 cm with two seedlings per hill. Phosphorus (60 kg P_2O_5 ha^{-1}) was applied as basal fertilizer. Potassium (105 kg K_2O ha^{-1}) was split equally between basal and panicle-initiation applications. Water management employed a strategy of shallow flooding (to a depth of 1–2 cm)–midseason drainage–reflooding (to a depth of 5–8 cm)–moist intermittent irrigation. Weeds were managed by a combination of herbicide spraying (20% paraquat, diluted 5 mL L^{-1} and applied at 750 L ha^{-1} at 7 days before transplanting) and hand weeding. Insects and diseases were intensively controlled by chemicals to avoid yield loss. At maturity, grain yield was determined from a 5-m^2 area in each plot and adjusted to a standard moisture content of 0.135 g H_2O g^{-1}.

2.2. Field experiment II

This experiment was conducted in Haikou (19°45′N, 110°11′E, 26 m a.s.l.), Hainan province in the early rice-growing season in 2012. A double rice cropping system with conventional tillage was followed in the field before the experiment was conducted. The soil of the experimental field was a sandy loam with the following properties in the upper 20 cm layer: pH 5.92, organic matter 21.4 g kg^{-1}, total N 1.08 g kg^{-1}, available P 34.8 mg kg^{-1}, and available K 115 mg kg^{-1}. The hybrid rice cultivar Liangyoupeijiu was grown under four N treatments (Table 1). The N treatments were arranged in a completely randomized block design with three replications and plot size of 20 m^2. Rice plants were established by zero-tillage seedling throwing. Seedling throwing is a simplified cultivation technology in which rice seedlings with soil on their roots are thrown by hand into fields. Pre-germinated seeds were sown in seedling trays. Thirty-day old seedlings were thrown at a hill spacing of 20 cm × 27 cm with two seedlings per hill. Crop management followed the practices used in field experiment I. At maturity, grain yield was determined from a 5-m^2 area in each plot and adjusted to the standard moisture content of 0.135 g H_2O g^{-1}.

Please cite this article as: M. Huang, et al., Improving nitrogen management for zero-tillage rice in China, The Crop Journal (2018), https://doi.org/10.1016/j.cj.2018.03.002