



Methodology of fertilizer recommendation based on yield response and agronomic efficiency for rice in China



Xinpeng Xu^{a,b}, Ping He^{b,c,*}, Fuqiang Yang^b, Jinchuan Ma^b, Mirasol F. Pampolino^d, Adrian M. Johnston^e, Wei Zhou^{b,*}

^a Institute of Plant Nutrition and Resources, Beijing Academy of Agriculture and Forestry Sciences, Beijing Engineering Technology Research Center for Slow/Controlled-Release Fertilizer, Beijing 100097, PR China

^b Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences (CAAS), Beijing 100081, PR China

^c International Plant Nutrition Institute (IPNI) China Program, CAAS-IPNI Joint Lab for Plant Nutrition Innovation Research, Beijing 100081, PR China

^d International Plant Nutrition Institute (IPNI), Southeast Asia Program, c/o IRRI, Los Baños, Laguna, Philippines

^e International Plant Nutrition Institute (IPNI), 102-411 Downey Road, Saskatoon, SK S7N4L8, Canada

ARTICLE INFO

Article history:

Received 18 August 2016

Received in revised form 15 February 2017

Accepted 20 February 2017

Keywords:

Rice
Nutrient Expert system
Yield response
Agronomic efficiency
Fertilizer recommendation

ABSTRACT

A science-based, reliable, and cost-effective fertilizer recommendation method is needed to solve problems of low nutrient use efficiency and yield brought about by inappropriate fertilization practices in rice (*Oryza sativa* L.). We collated results from 2218 on-farm experiments conducted between 2000 and 2013 in major rice-producing regions of China to establish scientific principles and develop a methodology that would support fertilizer recommendations for rice. The study analyzed the relationships among yield response, agronomic efficiency (AE), relative yield (the ratio of the yield without N or P or K to the yield of the full NPK), and soil indigenous nutrient supply. On average, yield responses to nitrogen (N), phosphorus (P), and potassium (K) fertilizer applications were 2.4, 0.9, and 1.0 t ha⁻¹, and the AE of N, P, and K application were 13.0, 12.7, and 8.4 kg kg⁻¹, respectively. Relative yield was used to classify the soil indigenous nutrient supply; average relative yields related to N, P, and K were 0.71, 0.89, and 0.89, respectively. A significant negative linear correlation was observed between yield response and relative yield, and a significant quadratic relationship was seen between yield response and AE. These findings allowed us to build the *Nutrient Expert (NE) for Rice* decision support system. With continuous optimization of the NE system in each cropping season, results confirmed the effectiveness of this method in improving rice yields and profits. Compared with farmers' practices (FP), NE significantly increased grain yield in early, middle, and late rice and increased gross profit in middle and late rice during the third year (2015) of field validation. In addition, with NE, there was greater improvement in the recovery efficiency of N (REN) in early, middle, and late rice and the AE of N and partial factor productivity of N (PFPN) in middle rice as compared with FP and soil testing (ST). Results of this study showed good agreement between simulated and observed AE of N application, indicating that NE is a promising nutrient decision support tool that can be used in China.

© 2017 Elsevier B.V. All rights reserved.

Abbreviations: AEN, agronomic efficiency of applied N; FP, farmers' fertilizer practice; IKS, indigenous potassium supply; INS, indigenous nitrogen supply; IPS, indigenous phosphorus supply; NE, Nutrient Expert; ST, soil testing; PFPN, partial factor productivity of applied N; REN, recovery efficiency of applied N.

* Corresponding authors at: Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences (CAAS), IPNI China Program, Beijing 100081, PR China.

E-mail addresses: phe@ipni.net (P. He), zhouwei02@caas.cn (W. Zhou).

<http://dx.doi.org/10.1016/j.fcr.2017.02.011>

0378-4290/© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Rice is one of the most important staple food worldwide, playing a crucial role in world food security. Improved rice varieties, soil and fertilizer management, water use efficiency, and weed and pest control have increased world rice yield by 59% from 1984 to 2014 (FAOSTAT, 2014). However, there remains an urgent need to maintain and increase crop yield to meet the demand of the growing population—world rice production must increase to 771.1 million tons by 2030 to meet food requirements (Van Nguyen and Ferrero, 2006). The challenge of increasing agricultural production in an economically viable way while maintaining the ecological

integrity of systems is the underlying aim of sustainable agriculture (Liang et al., 2013; Zhao et al., 2015). In 2014, the planting area for rice in China covered 30.8 million hectares and total rice yield reached 208.2 million tons, contributing 19% and 28% of world rice production, respectively (FAOSTAT, 2014).

The application of sufficient quantities of plant nutrients is necessary to increase rice yield and production, particularly in varieties with high yield potential (Mueller et al., 2012; Wang et al., 2012). However, fertilizer application by farmers is often kept constant over time or over large areas, rather than tailored to meet crop nutrient requirements. This results in unbalanced and inefficient fertilizer use and poor economic returns (Pampolino et al., 2007). Furthermore, excessive and unbalanced fertilization, especially over application of N and P fertilizers, also leads to low nutrient use efficiency (Qin et al., 2013), which is associated with negative impacts on the environment such as greenhouse gas emissions (Feng et al., 2013; Liu et al., 2015), land degradation, and freshwater pollution (Guo et al., 2010; Reidsma et al., 2012).

Better nutrient management is one of the key factors that guide intensive rice systems toward more intensified, diversified, and sustainable agricultural practices. The major challenge for rice nutrient management is the large variability in soil nutrient supply and yield response to nutrients between fields as a result of differences in crop-growing conditions, soil and crop management, and climate (He et al., 2015; Xu et al., 2016). Therefore, improved knowledge of intensive soil and crop management technologies is required to tailor nutrient management strategies to the specific characteristics of individual farms and fields (Dobermann and White, 1999). Many algorithms and methods have been developed for use in nutrient and crop management, which are widely used throughout the world (Nhamo et al., 2014; Chen et al., 2015). Examples include crop growth models (Zhu et al., 2008; Das et al., 2009; Sattari et al., 2014) and site-specific nutrient management (Alam et al., 2006; Pampolino et al., 2007). However, site-specific critical values of soil nutrient-supplying capacity and fertilizer use efficiency should be considered when making fertilizer recommendations.

A science-based, reliable, and cost-effective fertilizer recommendation method that can be readily transferred is required to address the problem of limited knowledge among farmers in China. The Nutrient Expert (NE) is a nutrient decision support system developed by the International Plant Nutrition Institute (IPNI) to help address these constraints. The NE system makes fertilizer recommendations using site-specific nutrient management principles based on yield response and agronomic efficiency (AE) and the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model (Janssen et al., 1990; Xu et al., 2015). As important parameters, yield response and AE have already been introduced into fertilizer recommendations for NE maize and wheat (Chuan et al., 2013; Xu et al., 2014). Similarly, there is a need to develop a more dynamic and site-specific nutrient management tool to increase crop yield and improve nutrient use efficiency in intensive rice systems in China. The objectives of this study were to (a) analyze yield response, AE, and soil indigenous nutrient supply in rice production areas of China, (b) develop *Nutrient Expert for Rice* in China, and (c) evaluate *Nutrient Expert for Rice* with field validations conducted in major rice-growing areas in China.

2. Materials and methods

2.1. Data sources

The data used in this study were obtained from 2218 field experiments conducted by the IPNI China Program and whose results were published in scientific journals from 2000 to 2013.

The database covered the main irrigated rice-producing regions and included a range of variables: (1) climate (i.e., semi-arid warm temperature, temperate, subhumid subtropical, cool temperature, and tropical), plant type by season (i.e., early rice, middle rice, late rice, and single season rice), and cropping systems (i.e., early-late rice, rape or winter wheat–middle rice, and monocropping systems); (2) cultivars including *indica* and *japonica* rice; and (3) fertilizer treatments including full N, P, and K fertilizer application, current farmers' practices, and nutrient omission plots of N, P, and K based on the previous two treatments. Measurements included yield and N, P, and K uptake in both straw and grain.

2.2. Description of the Nutrient Expert system

The NE system is a computer-based decision support tool that can rapidly provide nutrient recommendations for individual farmers based on their site-specific information with or without soil testing results. The NE integrates the complex nutrient management principles into an easily grasped and user-friendly software tailored to farm advisers, extension agents, and industry agronomists. The NE takes into account the most important factors affecting nutrient management recommendations and uses a systematic approach of capturing information. The determination of fertilizer N requirements is mainly based on expected yield response to fertilizer (i.e., the difference between attainable yield and N-limited yield or calculated based on attainable yield and relative yield when yield response data are not available) and target agronomic efficiencies of applied N (based on experiments with good crop management in seasons with typical climatic conditions). Relative yield is defined as the ratio of yield without N or P or K to that with full NPK. The NE approach is a dynamic nutrient management method that adjusts the amount of fertilizer N according to residual N from the previous crop, expected yield response to N application, and the indigenous N supply. The determination of fertilizer P and K requirements considers the internal efficiency combined with estimates of attainable yield, nutrient balance, and yield responses to the added nutrient within a specific field. The P and K balances of the previous crop are estimated and used to predict the residual P and K that can be carried over to the current crop.

The NE allows users to draw the required information from their own experience, knowledge, and practices and gives fertilizer management guidelines that are tailored to specific field characteristics and locally available fertilizer sources. The NE asks questions that help determine attainable yield and yield response to fertilizers and it integrates the "4R" nutrient management principles (applying the right source of nutrient at the right rate and the right time in the right place) in the fertilizer recommendation. A fertilizer recommendation can be made even in the absence of nutrient omission trial data. A large database of agronomic parameters and site characteristics from field trials is used to develop decision rules for evaluating soil indigenous supplies based on existing site-specific information, thereby enabling the development of fertilizer recommendation even if nutrient omission trial data were unavailable.

2.3. Parameterization of Nutrient Expert

The NE system scales maximum yield (Y_{max}) for a geographic region or growing environment according to site characteristics and individual farmer's yield to estimate attainable yield (Y_a). Y_{max} is the maximum yield that can be attained without any management limitation and is determined by crop models or suitable field experiments, whereas Y_a is determined from field trials for a typical climatic condition at a location with best management practices and without nutrient limitation. In the NE system, the yield gaps between maximum yield in field trials and farmers' practices are

Download English Version:

<https://daneshyari.com/en/article/5761523>

Download Persian Version:

<https://daneshyari.com/article/5761523>

[Daneshyari.com](https://daneshyari.com)