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Estimating a new approach of fertilizer recommendation across small-holder farms in China

Xinpeng Xu [a], Ping He [a,b,*], Shaojun Qiu [a], Mirasol F. Pampolino [c], Shicheng Zhao [a], Adrian M. Johnston [d], Wei Zhou [a,*]

[a] Ministry of Agriculture Key Laboratory of Plant Nutrition and Fertilizer, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences (CAAS), Beijing 100081, PR China
[b] International Plant Nutrition Institute (IPNI) China Program, CAAS-IPNI Joint Lab for Plant Nutrition Innovation Research, Beijing 100081, PR China
[c] International Plant Nutrition Institute (IPNI) Southeast Asia Program, PO Box 500 GPO, Penang 10670, Malaysia
[d] International Plant Nutrition Institute (IPNI), 102-411 Downey Road, Saskatoon S7N4L8, Canada

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ABSTRACT

Over and imbalanced fertilization has caused a series of environmental problems and threaten the food security in China. On-farm experiments were conducted from 2010 to 2012 at 408 sites in seven provinces to evaluate a new fertilizer recommendation approach, Nutrient Expert (NE) for Hybrid Maize (*Zea mays* L.), to meet the requirements of nutrient management for small-holder farms in China. Compared with the current farmers' fertilizer practices (FP), NE maintained grain yield and profitability, but decreased 30.4% of nitrogen (N) fertilizer (68 kg N ha^{-1}) and 11.3% of phosphorus (P) fertilizer (7 kg P_2O_5 ha^{-1}), while potassium (K) fertilizer rate increased by 38.8% (19 kg K_2O ha^{-1}). NE increased agronomic efficiency of applied N (AE_N) by 47.0%, N recovery efficiency (RE_N) by 51.0%, and partial factor productivity of applied N (PFP_N) by 35.5%. More importantly, NE decreased by 21.5 and 49.7 kg ha^{-1} of apparent N loss for summer maize and spring maize as compared with FP, respectively. The differences in agronomic and environmental parameters between NE and FP confirmed that the Nutrient Expert for Hybrid Maize is a promising nutrient decision support tool which not only increasing grain yield, nutrient use efficiency and profit, but also reducing nutrient loss and environmental pollution.

1. Introduction

Increases in food requirements, along with the decreasing arable land resources will generate great pressure on grain production in the future. A lot of research has shown that over-fertilization by farmers driven by the desire for higher yields does not always contribute to increase yield, however, this over-fertilization causes fertilizer waste and negative effects on the environment (Ju et al., 2009). Water pollution (Le et al., 2010), greenhouse gases emission (Zheng et al., 2004), nutrient accumulation in soil (Chen et al., 2006) and nutrient leaching (Zhang et al., 2005) due to over fertilization have become more and more serious problems in China. Typical N rate for some farmers have exceeded 500 kg ha^{-1} $year^{-1}$ for intensive wheat–maize systems in China (Cui et al., 2010a). Therefore, it is urgent to find a suitable fertilizer recommendation method, which can not only meet crop nutrient requirements for high yield, but also benefit the environment.

Numerous researches have been done to improve the use of indigenous soil nutrients, fertilizer use efficiency, and increase yield to its maximum potential. These included optimal N rate based on testing soil NO_3-N content in root layer (Cui et al., 2010b), fertilizer recommendation based on soil testing and yield targets and crop responses (He et al., 2009), fertilizer effect function equation (Sonar and Babhulkar, 2002), etc. These methods were effective for fertilizer recommendation, but they generally need comprehensive field sampling or annual setting field experiments due to the differences among soil types and climates in China. In addition, the past fertilizer recommendation usually involved in single nutrient, and the interaction among N, P and K were not considered.

Abbreviations: AE_N, Agronomic efficiency of applied N; FP, Farmers' fertilizer practice; GRF, Gross return above fertilizer cost; IKS, Indigenous potassium supply; INS, Indigenous nitrogen supply; IPS, Indigenous phosphorus supply; NE, Nutrient Expert; PFP_N, Partial factor productivity of applied N; RE_N, Recovery efficiency of applied N; TFC, Total fertilizer cost.

* Corresponding authors at: Ministry of Agriculture Key Laboratory of Plant Nutrition and fertilizer, Institute of Agricultural Resources and Regional Planning, 12 South Zhongguancun Street, Beijing, China. Tel.: +86 10 82105638; fax: +86 10 82106206.
E-mail addresses: phe@ipni.net, phe@caas.ac.cn (P. He), zhouwei02@caas.cn (W. Zhou).

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Here, we used large number of field-based academic research results to develop a dynamic field-specific management method, nutrient expert (NE) for hybrid maize, to optimize the supply and crop demand for nutrients and achieve balanced plant nutrition, and offered the advantage that agronomists, extension workers, and farmers could work together on the farm to estimate fertilizer nutrient requirements (Witt and Dobermann, 2002). The method is associated with the site-specific nutrient management (SSNM) principles, quantitative evaluation of the fertility of tropical soils (QUEFTS) model and meanwhile considers environmental, economic and agronomic benefits to determine the requirements of N, P, and K fertilizers. The SSNM strategies could increase yields through improving nutrients and crop managements. The core of SSNM method centers on determining fertilizer rate based on soil indigenous nutrient supply, crop yield and crop nutrient uptake (Dobermann and White, 1998; Dobermann and Witt, 2004; Koch et al., 2004; Witt et al., 2006; Dobermann et al., 2002; Buresh, 2009), and finally reduces a series of environmental problems including eutrophication of surface waters, nitrate pollution of groundwater, greenhouse gas emissions, and other forms of air pollution because of large inputs of synthetic N and P fertilizer (Ju et al., 2009). The QUEFTS model was used to develop relationships between grain yield and nutrient uptake in total above-ground dry matter at different levels of target yield (Janssen et al., 1990; Smaling and Janssen, 1993; Witt et al., 1999; Chuan et al., 2013a; Xu et al., 2013). A large dataset (n = 5000) from field experiments were collected from 2001 to 2010 to estimate balanced nutrient requirements used QUEFTS model (Xu et al., 2013). Understanding nutrient uptake at target yield contributes to optimize fertilizer rate, calculate nutrient balance and helps to lessen pollution from fertilizer application (Chuan et al., 2013b; Xu et al., 2014).

The aim of this study is to evaluate the method, nutrient expert (NE) for hybrid maize, to meet the requirements of nutrient management for small-holder farms in China through field experiments conducted across seven provinces from 2010 to 2012 in Northeast and North Central China. Grain yield, nutrient uptake and efficiency parameters were collected to evaluate the agronomic performance, and fertilizer cost and net profit over fertilizer cost were assessed to evaluate the economic performance. Finally, the apparent nitrogen losses were analyzed between NE and farmers' practice (FP) to evaluate the environmental performance of the Nutrient Expert for Hybrid Maize decision support system.

2. Materials and methods

2.1. Software configuration

The nutrient expert (NE) for hybrid maize uses SSNM principles, which based on yield response (YR) and agronomic efficiency (AE), and the QUEFTS simulated optimal nutrient uptake. As a computer-based decision support tool, it contains five modules: (1) current NM practice, (2) planting density, (3) SSNM rates, (4) sources and

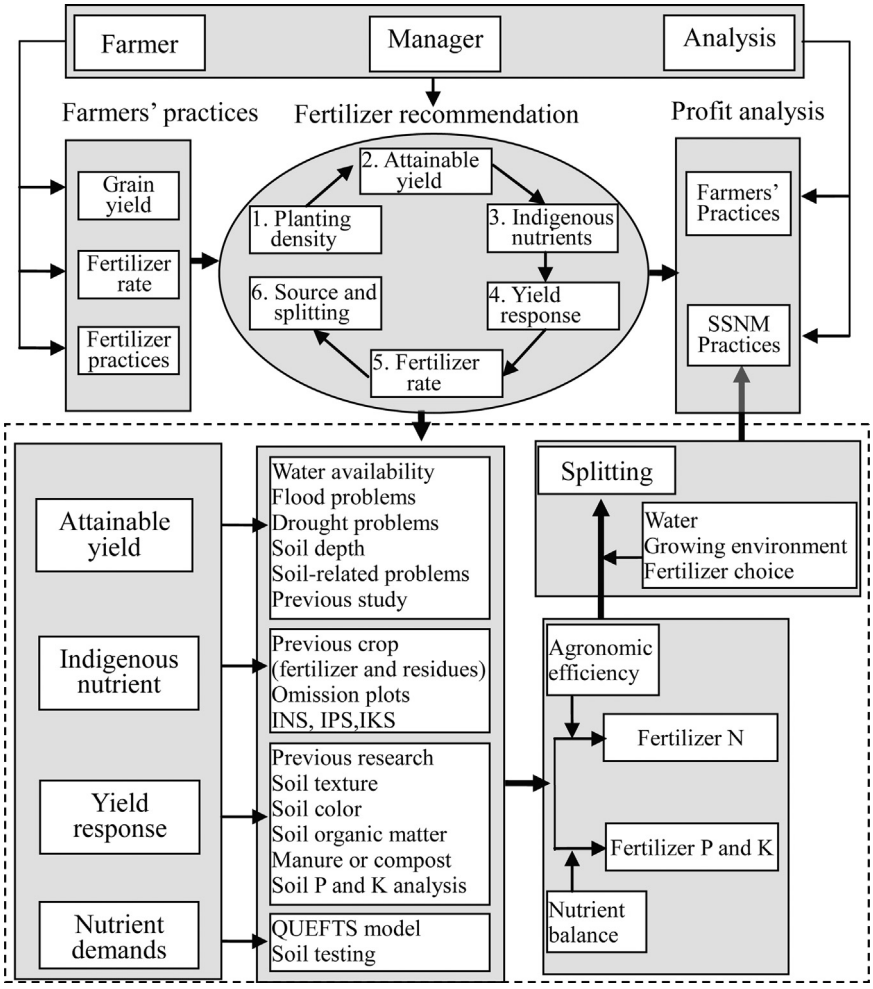

Fig. 1. The components and decision flow chart of Nutrient Expert for Hybrid Maize.