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Research article

Estimation of nitrogen supply for winter wheat production through a long-term field trial in China

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ABSTRACT

Excessive synthetic nitrogen (N) applications, high mineral N accumulation and low N use efficiency (NUE) are current issues in intensively cultivated winter wheat production system impeding the sustainable development of agriculture in China. To solve these problems, soil accumulated N in the top 1 m of the soil profile before sowing (N_{soil}), returned straw-N from the previous maize crop (N_{straw}) and fertilizer N application ($N_{fertilizer}$) should be comprehensively considered N supply sources in N management. As such, the objective of this research was to determine the optimal total N supply (TN_{supply}) level needed to meet crop requirements while minimizing environmental impacts. A 9-year on-farm experiment was conducted in accordance with a split-plot design involving two different fertilizer management systems (main treatments) and three N application strategies (sub treatments). Extensive TN_{supply} levels (ranging from 61 kg ha^{-1} to 813 kg ha^{-1}) were detected, and relative yield (RY), N input and N output in response to the TN_{supply} were measured. The relationships between TN_{supply} and RY, N input, and N output strongly fit linear-plateau, linear, and linear-plateau models, respectively. The minimum TN_{supply} levels needed to achieve the maximum RY and N output were 325 and 392 kg ha^{-1}, respectively. On the basis of N supply capacity, the TN_{supply} was removed from the growing system by 61% (N input). As the N input increased past 209 kg ha^{-1}, the NUE declined, at which point the TN_{supply} reached 433 kg ha^{-1}. Therefore, the suitable TN_{supply} should range from 325 kg ha^{-1} (ensuring a total N supply for high yield and N uptake) to 433 kg ha^{-1} (obtaining a relatively higher NUE and less N loss to the environment). The TN_{supply} was highlighted to be an indicator for use in N management recommendations. Considering the average high N accumulation in winter wheat production systems, N management should essentially take into account the consumption of N_{soil}, the levels of N_{straw} and the minimum application of $N_{fertilizer}$ to obtain high yields while minimizing environmental impacts under suitable TN_{supply} levels.

1. Introduction

Approximately 30% of the global synthetic nitrogen (N) fertilizer is applied in China (Heffer, 2016). The recovery efficiencies of N are only 28.3%, 28.2%, and 26.1% for rice, wheat, and maize, respectively, which are far behind those in America and in European countries (Zhang et al., 2008). Excessive use of N and low N use efficiency (NUE) have caused a series of environmental impacts, such as reactive N emissions, groundwater pollution and soil acidification (Ju et al., 2006; Zhang et al., 2012b; Huang et al., 2017).

Wheat plays a significant role in feeding the global population (Liu et al., 2016; Fischer and Connor, 2018). In China, winter wheat accounts for 93.7% of the total wheat planting area and 95.1% of the total national wheat production, which is distributed mainly in North China (China agriculture yearbook, 2018). To obtain high grain yields, smallholder famers have been applying large amounts of N fertilizer during the past two decades. The average N application rate exceeds 350 kg ha^{-1} during the winter wheat growing season (Cui et al., 2008a;

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