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Comprehensive environmental impacts of fertilizer application vary among different crops: Implications for the adjustment of agricultural structure aimed to reduce fertilizer use

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ABSTRACT

Although empirical correlations between fertilizer application rate and nitrogen (N) loss have been demonstrated, the differences in overall environmental impacts of fertilizer application among different crops have not been thoroughly elucidated to date. We investigated the fate of ^{15}N-labeled fertilizer in the plant-soil-air-water system across various crops (i.e., garlic, oilseed rape, and broad bean) by quantifying the N fluxes of various pathways combined with a pot experiment, a rainfall-simulating experiment, and ^{15}N tracer techniques. Hence, we compared the differences between different crops in the overall environmental impacts of fertilizer application. We found that N amount by plant uptake varied among these different crops but with little variation in fertilizer use efficiency (FUE). The residual N amounts in soil were significantly different in these crops due to statistically non-differential soil residual percentages, consistent with the differences in the application rate of N fertilizer and FUE. Further, evidently different overall environmental impacts of fertilizer application occurred among these crops, including gaseous loss of fertilizer N and potentially hydrologic loss of soil residual N from fertilizer. The highest gaseous N loss, including ammonia (NH_3) volatilization and nitrous oxide (N_2O) emissions occurred in garlic system, and the lowest occurred in broad bean. Moreover, potentially hydrologic loss of soil residual N in the garlic system was higher than in the other two crop systems, and the least was observed in the broad bean system. Therefore, attempts to reduce fertilizer application could benefit from considering the difference in overall environmental impacts of fertilizer application between different crop systems. The shift from crops with high environmental impacts to that with low impacts can largely reduce the regional N pollution.

1. Introduction

Increased application of fertilizer nitrogen (N) has significantly improved food production, but has simultaneously resulted in a cascade of environmental problems (e.g., global warming, air pollution, water quality degradation, and soil acidification) due to excessive or unreasonable application (Conant et al., 2013; Gu et al., 2015; Ju et al., 2009; Sutton et al., 2011; Zeng et al., 2017; Zuo et al., 2018). Approximately 27 Tg of the fertilizer N was used annually for food production during 2001–2010 in China (Yan et al., 2014), however, only 36–39% was taken up by plant (from 2003 through 2010) (Gu et al., 2017), which resulted in a substantial percentage of fertilizer N lost to the environment through ammonia volatilization, denitrification, leaching and runoff, etc. (Ju et al., 2009; Zhou et al., 2017a). A significant fraction of the fertilizer N applied to the cropland enters the freshwater systems and is transported by rivers to coastal areas, resulting in eutrophication of coastal and marine ecosystems (Huang et al., 2017; Mabaya et al., 2017; Strokal et al., 2014).

China started to reduce the fertilizer use dating from 2015 by implementing an announced ‘Zero Increase Action Plan’ for the national fertilizer use by 2020, which aimed to reduce the environmental costs associated with food production (Liu et al., 2016b). Improving the N use efficiency (NUE) is central to fertilizer reduction (Chen et al., 2014). Enhanced-efficiency fertilizers (e.g., polymer-coated fertilizers, nitrification inhibitors, urease inhibitors, and double inhibitors) (Li et al., 2018a), knowledge-based N management (e.g., controlled-release N fertilizer, nitrification inhibitor and urease inhibitor, higher splitting frequency of fertilizer N application, lower basal N fertilizer proportion,

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