Can knowledge-based N management produce more staple grain with lower greenhouse gas emission and reactive nitrogen pollution? A meta-analysis

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Knowledge-based nitrogen (N) management, which is designed for a better synchronization of crop N demand with N supply, is critical for global food security and environmental sustainability. Yet, a comprehensive assessment on how these N management practices affect food production, greenhouse gas emission (GHG) and N pollution in China is lacking. We compiled the results of 376 studies (1166 observations) to evaluate the overall effects of seven knowledge-based N management practices on crop productivity, nitrous oxide (N$_2$O) emission, and major reactive N (Nr) losses (ammonia, NH$_3$; N leaching and runoff), for staple grain (rice, wheat and corn) production in China. These practices included the application of controlled-release N fertilizer, nitrification inhibitor (NI) and urease inhibitor (UI), higher splitting frequency of fertilizer N application, lower basal N fertilizer (BF) proportion, deep placement of N fertilizer, and optimal N rate based on soil N test. Our results showed that, compared to traditional N management, these knowledge-based N practices significantly increased grain yields by 1.3 to 10.0%, which is attributed to the higher aboveground N uptake (5.1–12.1%) and N use efficiency in grain (8.0–48.2%). Moreover, these N management practices overall reduced GHG emission and Nr losses, by 5.4–39.8% for N$_2$O emission, 30.7–61.5% for NH$_3$ emission (except for the NI application), 13.6–37.3% for N leaching and 15.5–45.0% for N runoff. The use of NI increased NH$_3$ emission by 27.5% (9.0–56.0%), which deserves extra attention. The cost and benefit analysis indicated that the yield profit of these N management practices exceeded the corresponding input cost, which resulted in a significant increase of the net economic benefit by 2.9–12.6%. These results suggest that knowledge-based N management practice can be considered an effective way to ensure food security and improve environmental sustainability, while increasing economic return.