Reduction in nitrogen fertilizer-induced greenhouse gas emissions by BNI-enabled wheat

Since the beginning of the "Green Revolution," nitrogen (N) fertilizer consumption worldwide has increased ninefold. Soil nitrifier activity and nitrification have been increased by high fertilization rates, resulting in declining agronomic N-use efficiency (NUE) and an increase in environmental problems. The agronomic NUE for cereals is reported to be 30–50%. The remaining N is partially lost to the environment, exacerbating groundwater pollution by nitrate and climate change by nitrous oxide (N_2O) emissions from farmlands.

To increase NUE and to reduce the detrimental effects of reactive N on the environment, JIRCAS has focused on the release of root exudates from plants, a mechanism known as "Biological Nitrification Inhibition (BNI)." In collaboration with the International Center for Maize and Wheat Improvement (CIMMYT), JIRCAS has developed BNI-enabled wheat with a 30% nitrification inhibition rate. Aiming to reach carbon neutrality by 2050, the research team is currently developing BNI-enabled elite wheat varieties with a 40% reduction in nitrification.

Thus far, the potential impacts of deploying BNI-enabled elite wheat in wheat production systems have yet to be evaluated. The present study aims to evaluate the potential changes in fertilizer application rates, life cycle greenhouse gas (LC-GHG) emissions (Fig. 1), and NUE at the farm level. Moreover, it aims to evaluate the potential changes in worldwide nitrogen fertilizer-induced GHG emissions across wheat-harvested areas.

The study showed that BNI-enabled wheat with a 30% reduction in nitrification could reduce LC-GHG emissions by 12.3% and N fertilization by 11.7%, and improve NUE by 12.5% at the farm level by 2030 (Fig. 2, 30%). Furthermore, BNI-enabled wheat with a 40% reduction in nitrification could reduce LC-GHG emissions by 15.9% and N fertilization by 15.0%, and improve NUE by 16.7% by 2050 (Fig. 2, 40%). In addition, N fertilizer-induced GHG emissions could be reduced by 9.5% across wheat-harvested areas worldwide by 2050 if BNI-enabled wheat with a 40% reduction in nitrification is introduced only to areas suitable for BNI wheat (Fig. 3).

JIRCAS, together with CIMMYT, has presented estimates on the development of BNI-enabled wheat, which can reduce fertilizer use and GHG emissions, and will promote the use of BNI-enabled wheat in wheat-producing countries to achieve both high productivity and reduced environmental load from agriculture.

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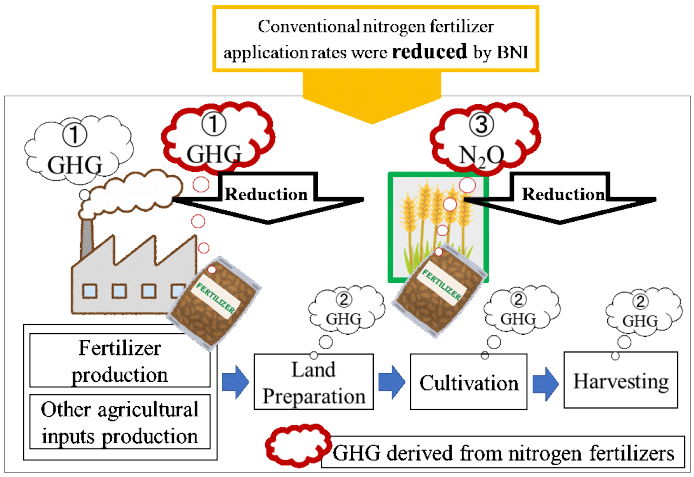

Fig. 1. Life Cycle Greenhouse Gas (GHG) emissions when nitrogen fertilizer-induced GHG emissions are reduced by BNI-enabled wheat

① GHG emissions from production of agricultural inputs such as fertilizer; ② GHG emissions from fuel consumption when machinery is used for land preparation, cultivation, and harvesting; ③ N_2O emissions from nitrogen fertilization applied in a field; and the sum of ①, ② and ③ is called "Life cycle greenhouse gas emissions." Nitrogen fertilizer-induced GHG emissions (GHG emissions from nitrogen fertilizer production and N_2O emissions from nitrogen fertilization, marked in red in Fig. 1) are reduced when nitrogen fertilizer application is reduced by BNI-enabled wheat.

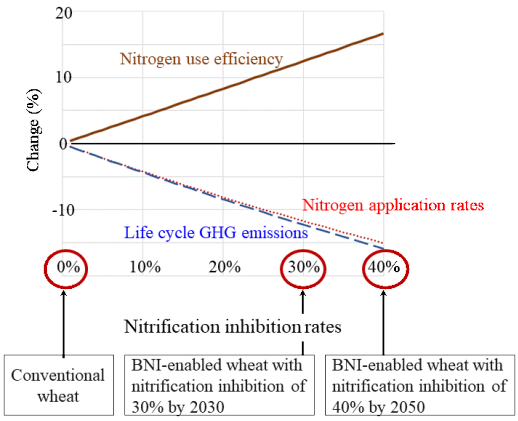

Fig. 2. Changes in life cycle GHG emissions, nitrogen fertilizer application rates, nitrogen-use efficiency, and nitrification inhibition rates caused by introduction of BNI-enabled wheat

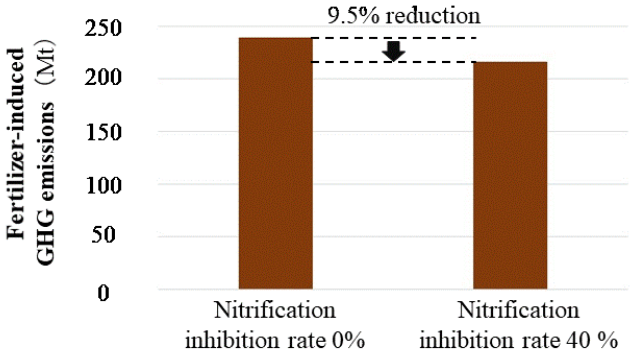

Fig. 3. Reduction in nitrogen fertilizer-induced GHG emissions when BNI-enabled wheat is introduced only to the area suitable for BNI-enabled wheat

Reference: Leon et al. (2022) *Environmental Science and Pollution Research* 29: 7153–7169. https://doi.org/10.1007/s11356-021-16132-2