



Foreword

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Published online: 18 March 2022

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Industrial production of synthetic nitrogen fertilizers (starting in the 1930s) and their large-scale infusion into agriculture (during the 1960s) have transformed global food production but brought major ecological and environmental problems. Harmful reactive N forms (NO_3^- , N_2O , NO) are generated through nitrification and denitrification reactions (a part of soil microbial activity), contaminating ecosystems, polluting waterbodies (ground water pollution and eutrophication of surface water bodies) and adding nitrous oxides (N_2O is a powerful greenhouse gas) to the atmosphere, contributing to global warming and climate change. Soil nitrifying activity is the primary driving factor for generation of these harmful reactive N forms and is associated with N fertilization in agriculture. A component of soil biological activity, i.e. nitrifier activity, has grown to become a major global problem, a lesson that emphasizes maintaining “harmony with nature.”

The Green Revolution, starting from the early 1960s, intensified the application of industrially produced N fertilizers in farming, led to food security for billions of people and transformed human society in the twenty-first century. However, indiscriminate use of N fertilizers has brought major changes in chemical and physical properties of soils and caused dramatic shifts in microbial dynamics, resulting in massive ecological and environmental problems that threaten the sustainability of production systems and endanger food

security for the future. Nitrogen fertilizer use has grown 20-fold since the 60 s to reach present levels of 150 Tg y^{-1} and is expected to reach 300 Tg y^{-1} by 2050 (to double food production from present levels), clearly in an unsustainable path. The last six decades of Green Revolution made farmlands extremely “N-leaky”, with agronomic- N use efficiency (NUE) as low as 0.25 to 0.30, indicating massive N losses. Reducing soil-nitrifier activity is thus paramount to reducing N leakage from agriculture. Synthetic nitrification inhibitors (SNIs) were invented in the 60 s but have not been widely adopted in production agriculture due to lack of cost-effectiveness and inconsistent field performance. Also, the accumulation of SNI residues in milk led to prohibition of their use in grazed pastures of intensive dairy farming.

The concept of plant-produced nitrification inhibitors from root systems was introduced in 2004 and termed ‘biological nitrification inhibition’ (BNI); the direct inhibitory impact from BNIs (released from roots through exudation) is demonstrated using a recombinant luminescent *Nitrosomonas* assay and has become the ‘bedrock’ of BNI research. Definitive evidence for BNI function was first shown in tropical pasture grass (*Brachiaria humidicola*) in 2006. Delivering nitrification inhibitors through plant root- network is perhaps the most effective way to control soil nitrifier- activity and limit the generation of harmful reactive-N -forms. Since then, BNI function has been reported for staple crops including wheat, rice, sorghum, and maize, and for uncultivated grasses and trees. Many novel BNI compounds have been discovered and patented, but much remains unknown about BNI. We are beginning to understand the regulating factors (both internal and external) for the synthesis and release of BNI compounds from plant roots. Heritable genetic variability for BNI-capacity (i.e. strength of BNIs production from root systems) has been reported in sorghum, wheat, maize, and rice, a pre-requisite for enhancing BNI through selection and breeding. Such BNI-enabled crops will become integral parts of low-nitrifying production systems as we move away from the present “nitrate-centric” agriculture, which is polluting and inefficient.

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Important progress towards understanding BNI in the last 15 years is paving the way towards the objective of incorporating “BNI-traits” to increase or introduce BNI-capacity to new varieties of staple crops and pastures. Much remains to be done to evolve this into BNI- technology, potentially providing “climate credits” (by limiting N_2O/NO emissions and N losses). If sufficient genetic- BNI-capacity is introduced into pasture and crop- root- systems, the generation of reactive- N- forms will be reduced. Currently BNI- research is largely driven by plant scientists, supported by phytochemists, physiologists, geneticists, molecular breeders, classical breeders, ecologists,

microbial- ecologists and agronomists. Work by soil scientists will strengthen efforts to assess benefits of BNI from a production system level and improve our understanding of the circular-N-movement often observed in natural ecosystems. We hope this special issue will stimulate interest and position BNI research for a long-term goal of shifting crop N nutrition towards an ‘ammonium-centric’ future.

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