A systematic approach to research on the development of nitrification inhibitors from indigenous resources

Nitrification inhibitors are chemical agents that inhibit or rather retard nitrification in soil or microbial culture by a sort of family planning among the nitrifying bacteria. Specific nitrification inhibitors are compounds and materials that retard the oxidation of ammonium to nitrite, without affecting the subsequent oxidation of nitrite to nitrate. Interest in the use of nitrification inhibitors stems from the fact that retardation or slowing down of nitrification in the soil reduces the N loss by leaching and denitrification following nitrification[1–3]. The literature on nitrification inhibitors is vast and is indicative of the interest in the use of nitrification inhibitors for controlling nitrification of ammonium and ammonium-forming fertilizers in the soil for improving N utilization by crops and for checking nitrate contamination of surface and groundwater[1–7].

However, despite great interest in nitrification inhibitors, only a few compounds have been adopted for agricultural and environmental use. The main problem seems to be the high cost involved in the development and subsequent use of the nitrification inhibitors in the low-input, practical agriculture in developing countries like India. In addition, the variable result often obtained is their use under field conditions in the tropical regions[8]. There is, however, a continuing need to direct research efforts to develop nitrification inhibitors that are inexpensive, readily available locally, and most of all, are effective at reasonable rates of application[7].

In India, there exists a wealth of plant resources that possess biocidal activity. In earlier research in this area, a number of plant products were used as sources of plant nutrients especially, with advantage. Following this finding a number of non-edible oilseed cakes and their extractives and isolates possessing biological activity were evaluated as N fertilizer amendments for regulating nitrification in the soil and their effects on utilization of N by crops[7]. Among these, neem (*Azadirachta indica* L.) and karanj (*Pongamia glabra* Vent) seed cakes (obtained by defatting of the seeds) and their various extractives and isolates have been most researched. In addition, plant polyphenols, vegetable tannins and waste tea products have been found to retard nitrification in the soil[7]. Recent research with mint essential oils from *M. arvensis* and *M. spicata* demonstrated that the *M. spicata* whole essential oil and the *M. arvensis* dementholated essential oil possess nitrification inhibitory activity. Application of these materials, rich in specific terpenes and the semi-synthetic products of individual terpenes of these oils found to possess a variety of microbiocidal activity, was reported to improve N utilization by wheat and rice crops in the field[9].

There is obvious need to further exploit indigenously available material as sources and for developing nitrification inhibitors using a structured approach[8]. This research would involve a coordinated effort from various disciplines (organic chemistry, microbiology, soil chemistry and agronomy) based on two approaches: (1) by empirical evaluation of a large number plant products and materials possessing general biocidal activity for retarding nitrification in soil, and (2) by identification of the functional groups responsible for the nitrification inhibitory activity and then incorporating these functional groups in suitable synthetic compounds. For example, employing the second approach, it was discovered that furan ring in the compounds imparts the nitrification inhibitory property to varying degrees[10,11]. The first approach is simple and could be used for short-term research goals to develop nitrification inhibitors from locally available natural products. On the other hand, the second approach is needed for a longer-range research.

Through an integrated research in the laboratory (in microbial culture and soil), greenhouse (with plant) and field, suitable compounds would be identified along with functional groups that impart nitrification inhibitory activity. Initially, prospective compounds/materials would be evaluated in the laboratory tests using soil and/or microbial culture, and those found effective would be evaluated in the greenhouse assay. Materials/compounds found effective in the greenhouse test would qualify for evaluation in the field under well-characterized soil and environmental conditions.

The synthesis of compounds with nitrification inhibitory activity would remove any constraints related to the non-availability of the compounds/materials, once found effective. It has been observed that at times plant products have limited availability and that their amounts required for the regulation of nitrification are rather large compared to pure compounds[7].

Basic research is also needed for delineating the beneficial effects of plant products in the retardation of nitrification and slow-release effects through immobilization–mineralization[12]. To achieve this objective, N-15-labelled fertilizers are useful as researchers can follow the fate of N – as to how retardation of nitrification affects ammonium fixation and release, mineralization, immobilization and remineralization of N and other processes of the N cycle[2,12].

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