J. Nuclear Agric. Biol., 17 : 238–242 (1988)

Use of ^{15}N in Nitrification Inhibitor Studies with Special Reference to Indigenous Materials

K. L. SAHRAWAT

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru-502324

ABSTRACT

Non-edible oil seed cakes and their constituents have been advantageously used for increasing the efficiency of fertilizer nitrogen (N) for crop production. The beneficial effects of these materials have been attributed to retardation of nitrification, which lessen the loss of N associated with nitrification by leaching and denitrification in situations where these losses are high. However, it is possible that some of the effects of these materials could be due to immobilization-remineralization of N particularly when the carbonaceous materials are added with fertilizers at high rates. A methodology involving the use of ^{15}N-labelled fertilizers is advanced to sort out whether the beneficial effects of non-edible oil seed cakes and other materials are due to retardation of nitrification and or immobilization-remineralization of fertilizer N. Using the proposed technique it would be possible to make realistic evaluation of the wealth of indigenous products as nitrification inhibitors. Following the proposed approach it would also be possible to widen the scope and depth of research in this area for ultimately better exploitation of indigenous materials as nitrification inhibitors.

Key words : Non-edible oil seed cakes, extractives, slow-release, retardation of nitrification, immobilization-remineralization of N

Fertilizers in general and N fertilizers in particular have made a major contribution toward agricultural productivity, but there is continuing need to improve the efficiency of N fertilizer use for achieving more efficient production of food and fibre and minimizing fertilizer-related environmental stresses[1–4]. Among the loss mechanisms that contribute to low fertilizer N use efficiency are: denitrification, leaching, and ammonia volatilization. These loss mechanisms, with the exception of ammonia volatilization, are associated with and follow nitrification of soil ammonium or ammonium-forming fertilizers to nitrate.

Overview of recent trends in nitrification inhibitor research

Nitrogen use efficiency can be increased by agronmic and cultural practices *e.g.*, by split application, method of application, and application of N during the period of high plant N demand[1]. However, regulation of nitrification rate in soils by use of nitrification inhibitors holds promise and is becoming increasingly attractive. These chemicals retard nitrification in soil by slowing the rate of conversion of ammonium-N to nitrite-N without affecting the rate of oxidation of nitrite-N to nitrate-N. This will lessen the loss of N through leaching or denitrification in situations where these losses are high.

The literature on nitrification inhibitors is extensive[5-13]. However, despite a great deal of research on nitrification inhibitors during the past two decades, only a few compounds have been adopted for practical use in agriculture production. The main problems are: (i) the high cost involved in the development and registration of effective nitrification inhibitors, (ii) the economics of their use particularly in low-input agriculture, and (iii) the fact they have often given variable results. This, however, should not deter research efforts in developing nitrification inhibitors from indigenous resources so that their use is economical.

Work done in India has shown that non-edible oil seed cakes and their constituents particularly those of neem (*Azadirachta indica* L.) and karanja (*Pongamia glabra* Vent.) have the ability to retard nitrification. Data on retardation of nitrification by some constituents of neem and karanja seeds is given in Table 1. These and other indigenous materials have also been found useful in increasing the fertilizer N use efficiency in some situations[9,14,15]. However, their efficacy in increasing fertilizer N use efficiency cannot be wholly attributed to retardation of nitrification because immobilization of N cannot be discounted in situations where these carbonaceous materials are added to N fertilizers in rather high amounts.

Table 1. Comparison of retardation ot nitrification of urea N by karanjin, and alcohol extracts of karanja and neem seeds*

Nitrification inhibitor	Amount of inhibitor added (% of added N)	Retardation of nitrification (% at days)			
		15	30	45	60
Karanjin	5	57	62	47	31
	10	64	77	59	43
Karanj seed extract	20	64	10	38	3
	30	71	54	45	5
Neem seed extract	20	51	38	10	7
	30	43	62	47	11

*Retardation of nitrification was calculated from the nitrification rates obtained from the amounts of NH_4, NO_2. and NO_3 produced in soil samples treated with and without nitrification inhibitor

Use of ^{15}N for evaluating indigenous materials as nitrification inhibitors

The use of ^{15}N labelled fertilizers is imperative to sort out as to whether the beneficial effects of indigenous materials such as non-edible oil seed cakes are due to retardation of nitrification or due to slow-release following immobilization-remineralization cycle. It is suggested that ^{15}N-labelled fertilizers should be used for evaluating the nitrification iuhibitory capacity of indigenous plant products particularly those with high carbon content. It can be ascertained from such studies in laboratory and field as to what route fertilizer N follows whether via retardation of nitrification or via immobilization-remineralization.

Use of ^{15}N will also be helpful in developing a systematic approach in screening the wealth of non-edible oil seed cakes and their constituents that are available indigenously[9,16] for use as nitrification inhibitors for increasing the efficiency of fertilizer N use by crops. The approach advanced by Sahrawat[17] and Sahrawat and Keeney[18] (Fig. 1) can be used for identification and evaluation of nitrification inhibitors from indigenous resources. Using this approach it was established that the furan ring imparts nitrification inhibitory activity to karanjin, the most potent nitrification inhibitor isolated from karanja seeds (Table 2). Karanjin has nitrification

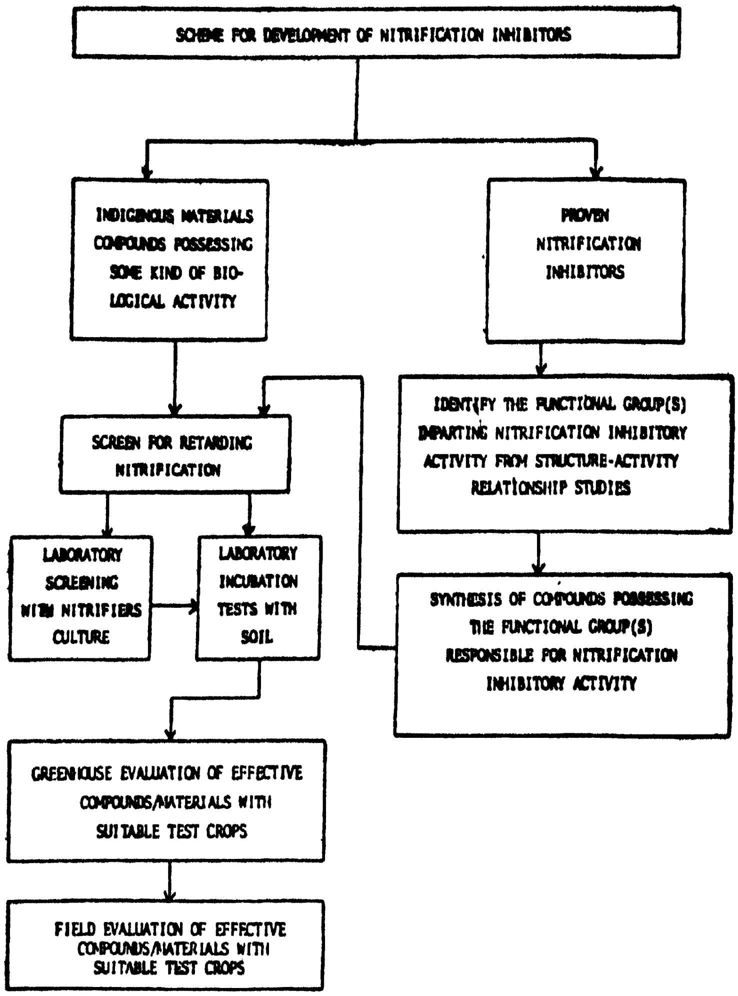

Fig. 1. Scheme for developing nitrification inhibitors[11]

inhibitors activity comparable to that of nitrapyrin [2-chloro-6(trichloromethyl) pyridine] (Table 3).

It is suggested that basic work should be done using ^{15}N-labelled fertilizers to evaluate potential indigenous materials for their ability to (i) retard nitrification and related processes such as emission of nitrous oxide (N_2O) and nitrite-N oxidation in soils, and (ii) utilization of N by crop plants following nitrification inhibition or slow-release effect. Since urea is the most commonly used N fertilizer in India, it would be desirable to screen the indigenous materials for their effects on urea hydrolysis.

Use of ^{15}N is also useful in studying the fate of N where nitrification is retarded in soils by patented and established nitrification inhibitors such as nitrapyrin [2-chloro-6-(trichloromethyl) pyridine]. For example, how inhibition of nitrification affects (i) ammonium fixation, (ii) N immobilization and its release, and (iii) ammonia volatilization can be easily studied by use of ^{15}N-labelled fertilizers.

Table 2. Effects of karanjin and its structural analogues on retardation of nitrificaton of urea in a sandy loam soil*

Nitrification inhibitor	Furan ring in the molecule present or absent	Retardation of nitrification % at 15 days of incubati o
Karanjin	Present	47
Karanj ketone	Present	44
Karanjonol	Present	28
Dihydro-karanjin	Absent	0

*Urea was added at a rate of 200 mg N kg^{-1} soil and the test nitrification inhbitors at rate of 5% of the urea N added

Table 3. Comparative evaluation of karanjin and nitrapyrin for retading nitrification in a san loam soil*

Treatment		Retardation of nitrification, % at weeks			
Fertilizer	Inhibitor	1	3	5	7
Ammonium sulfate	Karanjin	64	71	54	51
	Nitrapyrin	64	78	65	54
Urea	Karanjin	72	71	53	51
	Nitrapyrin	78	78	65	52

*Urea and ammonium sulfate were added at a rate of 200 mg N kg^{-1} soil and the inhibitoı at a rate of 5% of the fertilizer N added

Availability of locally produced ^{15}N-labelled fertilizers provides an opportı nity to agronomists, soil scientists, microbiologists, and chemical technologists ı conduct refined research for realistic evaluation of indigenous materials as nitrificatio inhibitors. For future developmental work, it is essential to delineate the beneficiı effects of the indigenous materials due to nitrification inhibition and slow-releas action. Such basic work is also needed to spearhead the present rather bogged-dow research on the use of indigenous nitrification inhibitors in improving agricultur productivity. It is a challenge as well as an opportunity for doing good innovativ research.

Acknowledgement

Approved for publication as ICRISAT C. P. No. 400.

References

1. Keeney, D. R., *Nitrogen in Agricultural Soils*, [Eds., F. J. Stevenson, J. M. Bremner, R. D. Hauck, & D. R. Keeney, *Am. Soc. Agron.*, Madison, Wis., USA, (1982) 605.].

2. Delwiche, C. C. (Ed.), *Denitrification, Nitrification, and Nitrous oxide*, [John Wiley, New York, USA (1981)].

3. Greenwood, D. J., *Nitrogen Cycling in Ecosystems of Latin America and the Caribbean*, [Eds. G. P. Robertson, R. Herrera, T. Rosswall, *Martin Nijhoff*, The Hague (1982) 54]

4. Sahrawat, K. L. & Keeney, D. R., *Adv. Soil Sci.*, 4 (1986) 103.

5. Gasser, J. K. R., *Soils Fert.*, 33 (1970) 547.

6. Prasad, R., Rajale, G. B. & Lakhdive, B. A., *Adv. Agron.*, 23 (1971) 337.

7. Hauck, R. D., *Organic Chemicals in the Soil Environment, Part B*, [Eds. C. A. I. Goring, Goring, J. W. Hamaker, Marcal Dekker, New York, USA (1972) 633].

8. Meisinger, J. J., Randall, G. W., & Vitosh, M. L. (Eds.), *Nitrificantion Inhibitors—Potentials and Limitations* [*Am. Soc. Agron.*, Madison, Wis., USA (1980)].

9. Sahrawat, K. L., *Pl. Soil*, (1980) 335.

10. Mulvaney, R. L. & Bremner, J. M., *Soil Biochemistry, Vol. 5*, [Eds. E. A. Paul & J. N. Ladd, *Marcel Dekker*, New York, USA (1981) 153].

11. Sahrawat, K. L. & Keeney, D. R., *J. Plant Nutr.*, 7 (1984) 1251.

12. Slangen, J. H. G. & Kerkvoff. P., *Fert. Res.*, 5 (1984) 1.

13. Sahrawat, K. L., *Soil Biology : Proc. National Symposium on Current Trends in Soil Biology*, [Haryana Agril. Univ., Hisar, Haryana (1986) 85].

14. Bains, S. S., Prasad, R. & Bhatia, P. C., *Fert. News*, 16 (1971) 30.

15. Prasad, R., *Fert. News*, 24 (1979) 25.

16. Vimal, O. P. & Naphade, K. T., *J. Sci. Ind. Res.*, 39 (1980) 197.

17. Sahrawat, K. L., *Plant Nutrition : Proc. 8th Int. Colloq. on Plant Analysis and Fertilizer Problems*, [Eds. A. R. Ferguson, R. L. Bieleski & I. B. Ferguson, *DSIR Information Series No.* 134. Wellington, Govt. Printer, New Zealand (1978) 431].

18. Sahrawat, K. L. & Keeney, D. R., *Commun. Soil Sci. Plant Analysis*, 16 (1985) 517.