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EFFECTS OF RETARDATION OF NITRIFICATION ON COMPOSITION AND YIELD OF CROPS

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ABSTRACT

Formulations of urea and ammonium fertilizers with nitrification inhibitors improve the efficiency of use of fertilizer nitrogen by plants in the specific situations where nitrification is accompanied by losses due to denitrification or leaching. But retardation of nitrification in soil may influence plant growth in ways other than by improving the total supply of nitrogen. In particular, the higher ratio of ammonium: nitrate may affect plant metabolism especially by influencing the uptake of some cations and anions. The obvious example is plants whose roots prefer to absorb nitrogen as nitrate; high concentration of NH_4^+-N in the soil solution may cause reduction in the uptake of N, and yield. However, retardation of nitrification also usually decreases accumulation of oxalate and nitrate, and stimulates uptake of phosphate in plant tissue and final produce. Reports on the effect of inhibitors on the accumulation of other nutrients (e.g. calcium, magnesium, iron and zinc) are conflicting. These results suggest that there is an obvious need for research to study the effects of retardation of nitrification on cation-anion balance, composition, quality and yield of a range of crops.

INTRODUCTION

It is recognised that the use of chemicals for retarding nitrification in soils holds promise for improving crop production and quality by improving the total supply of nitrogen in specific situations where nitrate formation results in the loss of fertilizer nitrogen due to leaching and denitrification (for review see Gasser 1970; Prasad et al. 1971; Sahrawat 1978, 1980).

But retardation of nitrification may influence plant growth in ways other than merely improving the total supply of nitrogen. For example, the higher ratio of NH_4^+-N: NO_3^--N may affect plant metabolism and yield especially by influencing the uptake of nitrogen, some cations and anions (Harada et al. 1968; Kirkby & Hughes 1970; Huber et al. 1977). This paper briefly examines and discusses the recent literature on the use of nitrification inhibitors with a view to understanding how the retardation of nitrification affects the yield and composition of crops. Such information assists in confining their use to situations where plant yield and composition is most favorably enhanced and in avoiding their use in cases where harmful or no effects accrue. It is recognized that the use of nitrification inhibitors may not be useful for plants that do not respond to relatively greater amounts of ammonium (Sahrawat 1980).

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Effects of ni[redacted]fication inhibitors on crop yield

There is ample evidence to show that retardation of nitrification increases crop yields by improving the use efficiency of fertilizer N (ammoniacal or urea) in situations where losses accompanying nitrate formation due to leaching and denitrification are high (see reviews by Prasad et al.1971; Huber et al. 1977; Sahrawat 1980). However, their use will not provide any advantage in situations where retardation of nitrification conserves fertilizer N, but there is no response to applied N. Their use may even be deleterious in situations where soil conditions promote losses through ammonia volatilization or where the plant does not metabolize equally well when fed with relatively higher amounts of NH_4^+ (for example, see Sahrawat 1980).

The results on the effect of nitrapyrin on yield of different crops like corn, cotton, potato, rice, spinach and winter wheat grown all over United States summarized by Huber et al. (1977), showed that yield advantages due to retardation of nitrification ranged from as low as 3.7% to as high as 200%. The effectiveness of inhibitors varied depending on the extent to which N loss occurred due to leaching and denitrification under diverse soil and environmental conditions where they were tested.

Nelson & Huber (1980) evaluated the effects on corn grain yield of Nitrapyrin (2-chloro-6- (trichloromethyl) pyridine) and Terrazole (5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole) added to fall applied anhydrous ammonia in a four year study at several locations in Indiana and found that nitrification inhibitors significantly increased the yield in 83% of the comparisons. The average yield responses due to nitrification inhibitor application ranged from 8 to 104% under diverse soil and environmental conditions (Table 1). Similarly these authors reported that the addition of nitrification inhibitors to fall-applied urea and anhydrous ammonia increased wheat yields by an average of 16.5% in studies extending over a period of 5 years.

TABLE 1

Effect on corn grain yield of Nitrapyrin and Terrazole added to fall-applied anhydrous ammonia (Nelson & Huber 1980)

Year	Nitrification inhibitor*	No. of comparisons	No. of significant yield increases	Average yield increase %
1973	Nitrapyrin	2	1	104
1974	Nitrapyrin	2	2	32
1975	Nitrapyrin	6	6	13
1978	Nitrapyrin	4	3	8
1978	Terrazole	4	3	12
All	-	18	15	24

* Nitrification inhibitors applied at a rate of 0.55 kg/ha.

[illegible] carried out in India has shown [redacted]t the use of inhibitors such as Nitrapyrin, neem (Azadirachta indica L.) and karanja (Pongamia glabra Vent) seed cakes and their constituents increased the yields of rice, maize, wheat, cotton and sugarcane, although the results have been variable (Sahrawat 1980; Prasad & Thomas 1982). The identity of the active compounds in neem seed cake and its extractives is not known. Undefined and variable composition of the neem seed cake and its derivatives used with respect to the active principles and unaccountability of the plant nutrients supplied by these materials makes it rather difficult to evaluate their potential as nitrification inhibitors. Detailed studies made by Sahrawat & Mukerjee (1977) have shown that karanjin, a furanoflavonoid is the major compound which imparts nitrification inhibitory property to karanja seed and its derivatives. Addition of karanjin and Nitrapyrin to ammonium sulfate and urea significantly increased the rice grain and drymatter yield in a greenhouse-pot study (Table 2).

TABLE 2

Effect on rice grain and drymatter yield of karanjin and Nitrapyrin added to ammonium sulfate and urea (150 kg N/ha) in greenhouse-pot experiment (Sahrawat & Mukerjee 1977)

Treatment	Ammonium sulfate: Grain	Ammonium sulfate: Grain + Straw	Urea: Grain	Urea: Grain + Straw
	g/pot			
Fertilizer alone	27.0	64.3	29.3	65.7
Fertilizer + Karanjin*	36.0	78.0	40.7	79.4
Fertilizer + Nitrapyrin*	36.0	76.3	36.0	78.0
L S D (0.05)	3.66	7.76	4.88	6.69

* Karanjin and nitrapyrin added at 5% rate of fertilizer N.

EFFECT OF RETARDATION OF NITRIFICATION ON PLANT COMPOSITION

Plant composition is influenced directly by the form of N (NH_4^+ or NO_3^-) through its differential metabolism or indirectly by influencing the uptake of some cations and anions (Harada et al. 1968; Kirkby and Hughes 1970; Riley and Barber 1971; Soon & Miller 1977).

Retardation of nitrification usually reduces the concentration of NO_3^--N in plant tissue but increases the concentration of total N and protein N (Huber et al. 1977, Table 3; Sahrawat 1980). Also plants supplied with NH_4^+-N usually contain lower amounts of cations such as calcium, magnesium and potassium and higher concentrations of anions such as phosphate, sulfate and chloride resulting in cation-anion imbalance (Parr 1973; Dibb & Welch 1976).

TABLE 3

Plant composition of field grown crops as affected by retarding nitrification of NH_4^+-N (Huber et al. 1977)

Plant	Tissue	Material	% change with retarding nitrification
Spinach	Leaf	NO_3^-	- 79.0
Wheat	Leaf	NO_3^--N	- 50.0
Lettuce	Leaf	NO_3^-	- 34.0
Field corn	Grain	Protein	+ 17.0
Sugarbeets	Leaf	Total N	+ 10.5
Sweet corn	Leaf	Total N	+ 11.7
Sweet corn	Leaf	Total N	+ 10.6
Rice	Grain	Protein	+ 8.1

In a recent study, a significant correlation was found between N and P concentration in ryegrass herbage after application of ammonium sulfate, to a soil of low nitrification activity; however, no correlation was found on a soil of moderate nitrification activity or after application of calcium nitrate to either soil (Steele & Saunders 1980). It was suggested that, on the soil with low nitrification activity, plants assimilated N in NH_4^+ form which stimulated P uptake. Kick & Massen (1973) found that treatment of ammonium sulfate with nitrification inhibitors, Nitrapyrin and DCD (dicyandiamide) markedly decreased the amounts of nitrate-N and total oxalic acid in spinach, due to absorption of more NH_4^+ than nitrate from soil treated with the nitrification inhibitors (Table 4).

Parr (1973) suggested that the difference in plant composition following retardation of nitrification may be due to i) effect on electron transfer system, ii) interferences with carbohydrate metabolism, iii) effects of pH, iv) ammonia toxicity and iv) ion uptake and competitive interactions.

Effects of nitrification inhibitors Nitrapyrin and dicyandiamide (DCD) on the nitrate and oxalic acid content of spinach with ammonium sulfate as N fertilizer (Kick & Massen 1973)

Treatment	NO_3-N %	Total oxalic acid %
Ammonium sulfate	1.15	7.80
Ammonium sulfate + DCD	0.35	2.84
Ammonium sulfate + Nitrapyrin	0.22	2.19

The use of nitrification inhibitors will promote ammonium nutrition. However, the currently available information is not sufficient to permit accurate prediction of the effects of inhibitors on plant composition under field conditions. If we want to exploit fully the use of these tools to modify the composition of plant tissue by controlling the form of N supplied to plants, further agronomic research in the area merits high priority.

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